UNIVERSITY OF ALBERTA

SYSTEMATIC ANALYSIS OF
WATER LOSS REDUCTION PROGRAM IN INDONESIA

by

Noeradhi ISKANDAR

A PROJECT REPORT

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The undersigned certifies that he has read, and recommends to the Faculty of Graduate Studies and Research, for acceptance, a project report entitled "SYSTEMATIC ANALYSIS OF WATER LOSS REDUCTION PROGRAM IN INDONESIA" submitted by Noeradhi Iskandar in partial fulfilment of the requirements for the degree of MASTER of ENGINEERING.

ABSTRACT

Water loss is a serious problem for the majority of water utilities in Indonesia. It is estimated that the average level of unaccounted-for water is ranging from 40 to 50 percent of the total water distributed to the systems. A study of water loss reduction program in 20 small and medium towns has shown that an aggressive reduction program supported by institutional development is considered to be a cost-effective means of reducing unaccounted-for water in most of the towns. It is now under serious consideration that the program will be extended as a national program covering all potential water utilities throughout the country.

In this report, the concept for the program implementation is discussed and evaluation of the results of the water loss reduction study in the 20 towns is carried out. The evaluation includes assessment of the appropriateness of the recommended leak detection methods and unaccounted-for water reduction target, and analysis of the economics of the program.

Utilizing the data and results from the study, a simple cost model, based on the predominant unit cost parameter, and feasibility indication of similar program for other small and medium towns are developed to assist in budget allocations and prioritizing the towns that need to be included if the extension of the program is to be decided.

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GLOSSARY

UFW	Unaccounted-for Water
WLR	Water Loss Reduction
ADB	Asian Development Bank
GOI	Government of Indonesia
DGHS	Directorate General of Human Settlements
MPW	Ministry of Public Works
REPELITA	Period Five Year Development Plan
PDAM	Municipal Water Enterprise
BPAM	Interim Municipal/Regional Water Enterprise
Kotamadya	Municipality
Kabupaten	District
Kecamatan	Sub-District
Rp.	Local Currency (Rupiah)
FIRR	Financial Internal Rate of Return
B/C	Benefit-Cost ratio
F/S	Feasibility Study
L/s	Litres/second
Lpcd	Litres/capita/day
h/d	Hours/day
DIP	Ductile Iron Pipe
GIP	Galvanized Iron Pipe
ACP	Asbestos Cement Pipe
PVC	Plastic Pipe (Polyvinyl Chloride)

I. INTRODUCTION

1.1. BACKGROUND

Water loss is a serious problem for the majority of water utilities throughout Indonesia. It is estimated that the national average for unaccounted-for water in existing water supply systems is approximately 43 percent of total production (Coffey and Partners Pty. Ltd., 1989). This fact has been recognized by the Government of Indonesia (GOI) as an area where major improvements in levels of efficiency should be achievable. An efficient unaccounted-for water reduction program would contribute to meeting the set target of water supply sub-sector development program in line with the national economic development in the context successive five-year development plans (REPELITA).

The control of unaccounted-for water is mainly a routine operational program of the water utility. But the Government of Indonesia is aware that the concerned municipal water utilities, especially in small and medium towns, generally lack of the experience, equipment and financial resources in order to introduce the necessary measures to decrease their water losses. Unlike the unaccounted-for water reduction program in large municipal water supply systems, which is technically feasible, financially viable and can be carried out on individual town basis, an extensive program for small and medium towns seems to be financially not justifiable and unattractive unless an appropriate and cost-effective method is available. The problem becomes more difficult as for most of the water supply systems in the country, the provision for the control of water losses was not carefully considered when the system were built.

For this reason the GOI under financial assistance from the Asian Development Bank (ADB) is introducing a new program, namely Water Loss Reduction Project,

which is designated to reduce unaccounted-for water in 20 municipal water supply systems. This is the first major attempt to find a systematic approach for solving the water loss problem in small and medium size water supply systems, which represent the majority of municipal water utilities in Indonesia. The program is expected to be an initial one which later, when the program in those 20 towns has proven to be cost effective and efficient, will be extended as a national program covering all similar water utilities throughout the country.

As the preparation for the program, a study using representation and extrapolation methods was carried out by a consortium of international and local consultants since October 1988 and completed in January 1991. The objectives of the study are to find the most appropriate concept for the implementation of water loss reduction program in those 20 towns but also replicable for other similar categories of towns, and to assess the feasibility for the project implementation in those 20 towns. Based on evaluation of various aspects the study recommends that a routine leak detection control program should be performed by each water utility. Three categories of leak detection equipment set based on the number of service connections are recommended (Lahmeyer Int. and Associates, January 1991). The study has also shown that the acceptable level of unaccounted-for water could vary for every town depending on characteristics of the system, existing percentage of unaccounted-for water, and financial situation of the water utilities. If the suggested level of unaccounted-for water, which is mentioned in the national technical guide-lines for water supply sub-sector development, i.e. 20 percent, is to be achieved, the study shows that the project is not financially justifiable for some of the towns.

Evaluation of the financial internal rate of return (FIRR) of the project for every town shows that only 14 towns have FIRR more than 10 percent, while the remaining six towns would have FIRR less than 10 percent. Two out of these six towns have

negative FIRR. A fairly broad comparison between the cost of the water loss reduction program with an expansion program for those 20 towns, if the same amount of additional water gained is to be provided through an expansion of plant capacity, was also given to facilitate the decision maker for its final decision to implement the project. The results are quite similar to the above mentioned financial evaluation results, showing that the water loss reduction project is more cost effective for 13 towns, is comparable for one town, and is less cost effective for the remaining six towns, compared to the expansion program. Since the implementation of the project will be financed through a loan from the ADB to the central government, in this case a 9 percent FIRR was used as the minimum indication of the feasibility of the project (Lahmeyer Int. and Associates, April 1990). Therefore, it was finally concluded that the project is technically feasible and financially viable for only 14 out of the 20 towns.

1.2. THE NEED OF COST MODEL AND FEASIBILITY INDICATIONS

According to recent national guide-lines for water supply sub-sector development, every development program for municipal water utilities should be made self-supporting project as much as possible except for emergency purposes. This is one of the most important indicators used in the assessment of the priority of the program in order to obtain the approval and financial support from the local and/or central government. Priority would also be given to the program of reducing unaccounted-for water to an acceptable level in order to make optimum use of existing systems (Coffey and Partners Pty., 1989).

Since more than 80 percent of municipal water supply systems in Indonesia can be categorized as small to medium size systems, and since the study has shown that the recommended program can not be financially justified for some of the towns, therefore

it will be quite useful to have a representative cost model and feasibility indications for the implementation of similar water loss reduction project in other towns outside those 20 towns. If the cost and feasibility indications of a similar water loss reduction project for a particular municipal water supply system can roughly be estimated using a representative model, the unnecessary cost for the investigation and feasibility assessment of the possibility of implementation of the project in that particular system can be avoided. The model can simply be used in an initial assessment for knowing the level of priority of a water loss reduction project in similar water supply systems in the future, if the water loss reduction program is to be extended as a national program.

1.3. OBJECTIVE AND SCOPE

It is important to evaluate the results of the Water Loss Reduction Study and to analyze the most important factors governing the cost and feasibility indications of a water loss reduction program for future development in water supply sector in Indonesia.

The objective of this study is to develop a representative cost model and feasibility indications of a water loss reduction program for small and medium size water supply systems in Indonesia, using the results of the water loss reduction project preparation in the 20 towns extensively. In order to do this, the necessary evaluation and analyses of the results of the previous study will be performed.

The scope of evaluation in this report, in general, can be summarized as follows :

- review of data on major components of unaccounted-for water,
- evaluation of the recommended leak detection methods and estimated possible reduction of unaccounted-for water,

- cost comparison of the water loss reduction project in the 20 towns and evaluation of major cost components,
- analyses and evaluation of the benefits of a water loss reduction program,
- analyses and selection of representative cost parameters for the development of the cost model and feasibility indications,
- evaluation and assessment of the adequacy of the model,
- discussion of the results of the evaluation in relation to the practical use of the model, and
- conclusions and recommendations for further refinement of the model.

II. WATER LOSS REDUCTION PROGRAM

2.1. BACKGROUND

Under the fourth Five-Year Development Plan / REPELITA IV (1984/85 - 1988/89) the Government of Indonesia aims to provide safe water supply to 75 percent of urban population by 1990 (Lahmeyer Int. and Associates, February 1989). This target could doubtfully be achieved due to the slow down in project implementation and some other limitations. This sub-sector program was expected to spill over to the 1990s. It was further realized that water loss due to leakages and other components of unaccounted-for water were becoming points of major concerns as the national average for unaccounted-for water is high. The Government of Indonesia considers that an efficient water loss reduction program would contribute to meeting the REPELITA goals by conserving scarce financial and water resources and by providing in the short run an alternative to expensive programs of further expansion of water supply systems.

In other countries, as well as in some projects in large cities in Indonesia, it has been demonstrated that an efficient program of water loss reduction generates enough saving to pay for itself, while there is the further benefit of delaying the need for major augmentation programs. Therefore the Government considers the need to introduce a new program for water loss reduction in the next Five-Year Development Plan. It is expected that a water loss reduction program is to be assigned routinely to each water utility, but the Government realizes their limited capability, experience and facilities in implementing this program. For this reason, a project designated to reduce unaccounted-for water in 20 selected towns is to be initiated under financial assistance from the Asian Development Bank.

2.2. OBJECTIVES AND SCOPE

The project that is expected to emerge will aim to reduce water loss occurrences in some 20 towns through a program based on cost-effective measures. The program will also include an institutional development component to support the technical measures to be taken in the project towns. This complementary measure will cover administrative procedures, staffing and human resources development, so the program could be implemented on a sustained basis.

Project components will be determined under a sub-project technical assistance and would likely to include the following major components :

- updating of records and inventory;
- replacement and servicing of customer water meters;
- waste water monitoring;
- leak detection and pipe repairs;
- system rehabilitation and replacement of poorly laid or corroded pipe;
- institutional development;
- improvement of operation and maintenance; and
- consultant services and training program.

2.3. PROJECT AREA

Twenty water supply systems in small and medium towns/cities were chosen as the proposed locations of the project. In relation with the intended approach that will be used in the study for the preparation of the project, described in Section 2.4, and possible extension of similar program to other towns in the future, the selection of project areas was made in such a way so that grouping of towns based on similar major characteristics is made possible. The selected systems could also be considered as

representative of the majority of water supply systems in Indonesia.

Topography was considered as a major characteristic for the towns and closely related to water loss aspect since there are differences in the distribution systems due to the topographical conditions such as soil type, system pressure, type of distribution system, etc. Considerations were also given to geographical distribution of the towns, socio-economic aspect, institutional, financial and other technical aspects such as system capacity, type of raw water source, percentage of unaccounted-for water, age of the system, etc.

The project towns are situated in seven provinces over two main islands in Western Indonesia, Sumatera and Java, as shown in Figure 2.1. The list of towns and their geographical/topographical situation is given in Table 2.1.

2.4. PROGRAM FORMULATION AND SCOPE

A sub project technical assistance was provided by the Asian Development Bank for the formulation of the program. At the end of 1987, the Directorate General of Human Settlements (Cipta Karya) of the Ministry of Public Works , as the executing agency, invited Consultants to make proposals for Consultant's services for the preparation of the Water Loss Reduction Project and Loan Proposal for the implementation of the project.

In September 1988 Lahmeyer International GmbH. in association with P.T. Resource Development Consultants (REDECON), P.T. Arkonin Engineering and P.T. PAS receive the Notice to Proceed and the Water Loss Reduction Study started in October 1988. The study was originally scheduled to be completed in July 1990, however, due to the delay in the procurement and supply of leak detection equipment and materials, it was just completed in January 1991.

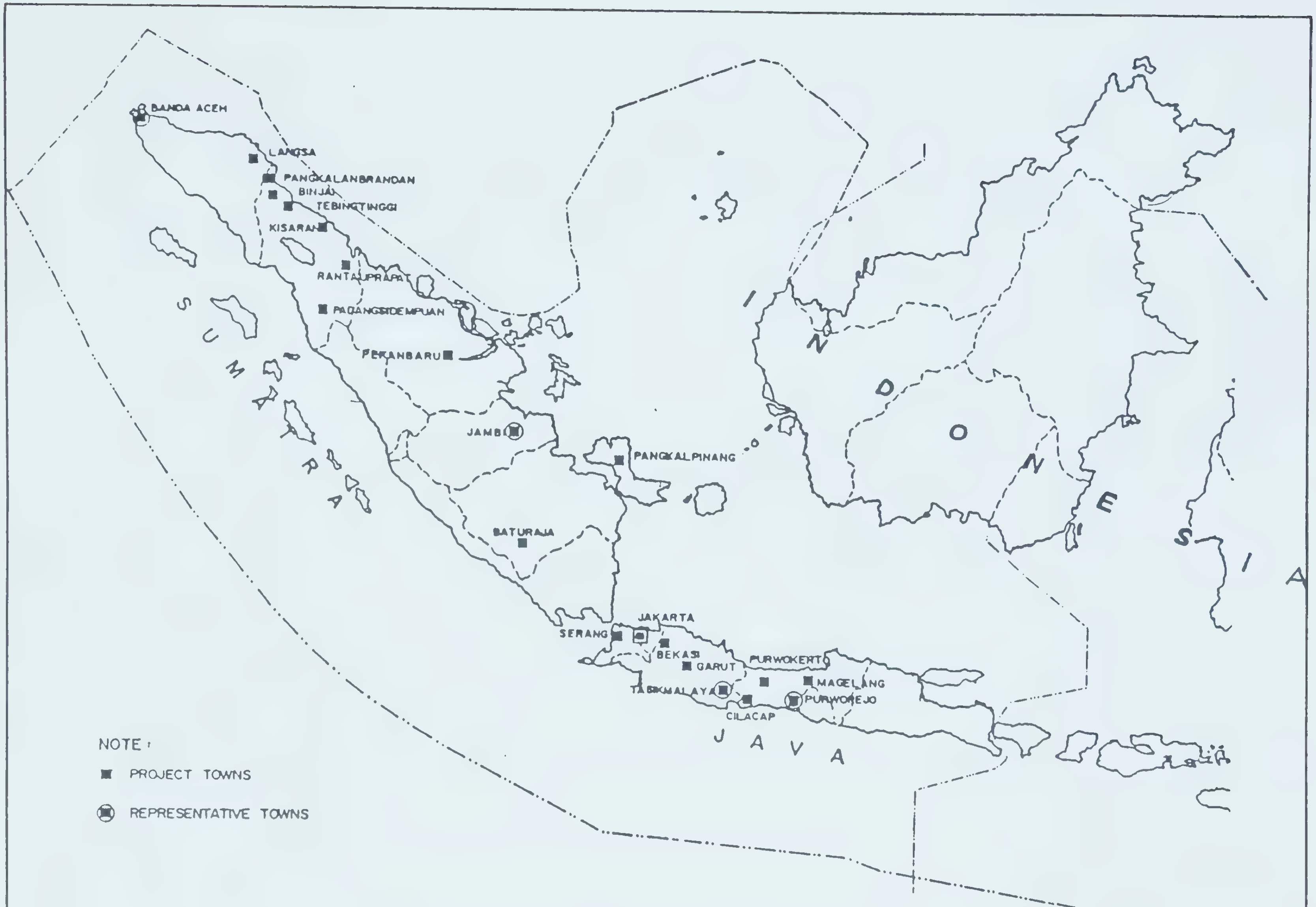


Figure 2.1. Location Map of Project Towns

Table 2.1. Topographical / Geographical Comparison of Towns

No.	TOWN (topography / geography)	SUMATERA Coastal	SUMATERA Lowland	SUMATERA Upland	JAVA Coastal	JAVA Lowland	JAVA Upland
1	Banda Aceh	*					
2	Langsa	*					
3	Pangkalan Brandan	*					
4	Binjai		*				
5	Tebing Tinggi		*				
6	Kisaran		*				
7	Rantau Prapat			*			
8	Padang Sidempuan			*			
9	Pakanbaru		*				
10	Jambi		*				
11	Pangkal Pinang		*				
12	Baturaja			*			
13	Serang					*	
14	Bekasi					*	
15	Garut						*
16	Tasikmalaya						*
17	Cilacap					*	
18	Purwokerto						*
19	Purworejo					*	
20	Magelang						*
	SUB TOTAL	3	6	3	0	4	4
	TOTAL	12			8		

Source : Lahmeyer Int. & Associates, February 1989 .

As to the need to expedite the program, the formulation of the project has been prepared using representation and extrapolation methods. In this case a detailed feasibility study was carried out using four selected, representative towns, while the remaining 16 towns were studied up to prefeasibility level. The scope of the consultant's works followed the terms of reference and comprised two parts, part A being divided into two phases. It can be outlined as follows :

Part A - Phase I : Identification Study

- field visits to 20 towns;
- selection of four representative towns;
- selection of pilot zones in the four selected towns and preparation of equipment and materials;
- preliminary institutional and economic studies; and
- training approach.

Part A - Phase II : Feasibility and Prefeasibility Studies

- performance of leak detection programs in 4 towns;
- training program;
- extrapolation for 16 towns;
- preliminary design and Feasibility studies for 4 towns;
- outline design and prefeasibility studies for 16 towns; and
- loan proposal for the implementation of the water loss reduction program.

Part B : Detailed Design and Tender Documents

- supplementary field surveys in 4 towns;
- detailed designs; and
- preparation of tender documents.

The schematic process of the Water Loss Reduction Study is given in Appendix A.

III. WATER LOSS REDUCTION STUDY OVERVIEW

3.1. SELECTION OF REPRESENTATIVE TOWNS

For the purpose of selection of representative towns, criteria for grouping, ranking and selection of pilot areas had been developed in the early stage of the study and are shown in Table B.1 (Appendix B).

3.1.1. Grouping of Towns

The criteria for grouping were chosen for the purpose of selection of 3 to 5 groups of towns of similar characteristics. Each town within a group should be representative of the group, and the results obtained from the studies and programs performed in the highest ranked town of each group should be suitable for extrapolation with regard to the remaining towns of the group.

It was agreed to use the criteria of topography and geographical distribution for the grouping of towns. As it was expected, topography has been considered as a major characteristic of the towns. Three groups of towns can be identified in accordance with their topographical location ; towns located in coastal areas, lowlands plain (flat) and upland plain (mountainous) areas.

The criterion of geographical distribution of the towns was used for the equal distribution of the representative towns over the islands of Sumatera and Java, mainly for the purpose that the distance to the remaining towns can be kept in a reasonable range, so that those towns not selected as representative towns could profit from the leak detection programs in the selected representative towns.

The criteria were applied for the compilation of groups in a way that the towns were divided into three groups according to their topographical situation, which were subdivided by their geographical distribution. Since only four towns could be selected as pilot towns, topography was conceded priority over geographical distribution. Taking into account the total number of towns in each group, it was agreed that four groups were chosen as indicated in Table B.2 (Appendix B). The final grouping is shown in the following table.

Table 3.1. Results of Grouping of Towns

Group No.	Location	No. of Towns
I	Coastal area / Sumatera	3
II	Lowland's area / Sumatera	6
III	Lowland's area / Java	4
IV	Upland area / Sumatera + Java	7

Source : Lahmeyer Int. & Associates, June 1989.

3.1.2. Ranking of Towns

The criteria for ranking were applied for the purpose of determining the sequence of towns in each group with the highest ranked towns being the most preferable for the performance of introductory leak detection program. The criteria were weighted according to their significance for the program and were given scores in accordance with the results of field investigations. The highest number of points indicates the highest ranked town per group.

A sequence of importance was determined for the ranking criteria, expressed by the headlines I to VI in Table 3.2. The criteria to comply with the headlines were taken

taken from Table B.1 (Appendix B), but limited to the number necessary to give sufficient evidence for each of the headlines.

The criteria were then weighted with regard to their importance, with the most important given a weight of 10 and the least important 3. The following table indicates the 24 criteria chosen for ranking and the weight applied to each criterion.

Table 3.2. Criteria for Ranking of Towns

Ranking Criteria		Weight
I	Water Loss Rate	
	1. Percentage of total water losses	10
II	Highest Benefits from Water Loss Reduction Program	
	2. Cost of water production	8
	3. Consumer candidates waiting	8
	4. rate of leakage (leaks per month)	8
III	Financial Ability and Assistance of Water Utilities	
	5. Financial situation (rate of return)	7
	6. Assistance of Water Utilities	7
IV	Water Distribution System Conditions	
	7. Type of distribution system	6
	8. Pipe materials	6
	9. Age of pipes	6
	10. Hours of service	6
V	Water Supply Service Conditions	
	11. Existing water source capacity	4
	12. Percentage of population served	4
VI	Opportunities for Future Expansion	
	13. New consumer connections per year	3
	14. Average water consumption	3

Source : Lahmeyer Int. & Associates, June 1989.

To the ranking criteria selected and weighted in the above table, a scoring system was used for the evaluation of the data collected during the field visits. Table B.3 in Appendix B shows the scores allocated to each of the data. The scores vary from 1 to 4. They were applied in such a way that the higher the need for the water loss reduction project, the higher the score. A summary of comparative table of the data used for ranking the towns is given in Table B.4 (Appendix B).

The total score for each criterion was calculated by multiplying the predicted scores for each of the criteria with the weight assigned to each criterion. The total scores for each town were then summed to arrive at the final total. The results of ranking process of the towns are summarized in Table 3.3 below.

Table 3.3. Summary of Rank of the Towns

Group No.	Town	Final Total Score	Rank
I	Banda Aceh	189	1
	Pangkalan Brandan	186	2
	Langsa	168	3
II	Jambi	215	1
	Binjai	196	2
	Tebing Tinggi	171	3
	Pakanbaru	171	4
	Pangkal Pinang	170	5
	Kisaran	158	6
III	Purworejo	199	1
	Bekasi	191	2
	Serang	169	3
	Cilacap	165	4
IV	Tasikmalaya	201	1
	Padang Sidempuan	189	2
	Magelang	184	3
	Purwokerto	177	4
	Rantau Prapat	157	5
	Baturaja	147	6
	Garut	136	7

Source : Lahmeyer Int. & Associates, June 1989.

As a result of the ranking process, the following towns are the first ranked for each group and therefore considered as the ones with the highest need for a water loss reduction project :

Group I	Banda Aceh
Group II	Jambi
Group III	Purworejo
Group IV	Tasikmalaya

3.1.3. Selection of Pilot Zones

Pilot zones were chosen in the four selected towns with the aim that they should be representative of respective town. Criteria considered applicable for the selection of pilot zones had been developed in connection with the grouping and ranking of the 20 towns and are mentioned in Table B.1 (Appendix B).

The approach to the selection of pilot zones considered that the following conditions were met :

- the pilot zones can be easily isolated;
- the pressure within the zones allows 24 hours water supply and is sufficient for leak detection operation;
- conditions in the pilot zones are suitable for extrapolation;
- consideration of future extension of the leak detection program;
- the possibility of minimizing the disturbance to the neighbouring supply areas while isolating the zones;
- the field works will not cause too much disruption of the traffic; and
- the pilot zones should comprise about 25 percent of the total consumers , if possible.

In addition to the above technical aspects, considerations to other aspects, e.g. administration/financial, institutional and socio-economic aspects had also been taken

into account for the selection of the pilot zones.

In order to comply with the fore-going approach, two or more zones have been selected in each of the four towns depending on the local conditions. The locations of the pilot zones in those towns are indicated in Figures 3.1 to 3.4.

3.2. LEAKAGE CONTROL PROGRAM

A leakage control program was performed in each of the selected pilot zones of the representative towns for the purpose of demonstrating the full range of leak detection measures and identifying the most appropriate and cost-effective measures. The whole program can be subdivided into three steps in accordance with work's activities schedule :

1. consumer and water meter survey;
2. preparation of pilot zones (installation of materials); and
3. performance of leak detection program.

Prior to the execution of the above program, some preparation works including evaluation of the leak detection methodology and equipment which will be used and assistance in the procurement of necessary equipment and materials, were performed. A preliminary water balance based upon available data was also made for each of the four towns to indicate the estimated level of each component of the unaccounted water. The balance had been made in terms of the volume of water distributed and the unaccounted is the difference between this volume and the volume recorded by the consumer meters. The average volume of water produced, distributed and sold during the last 12 months in each of the representative towns is shown in Table 3.4. The water losses indicated in the table were derived from the difference between water distributed and water sold.

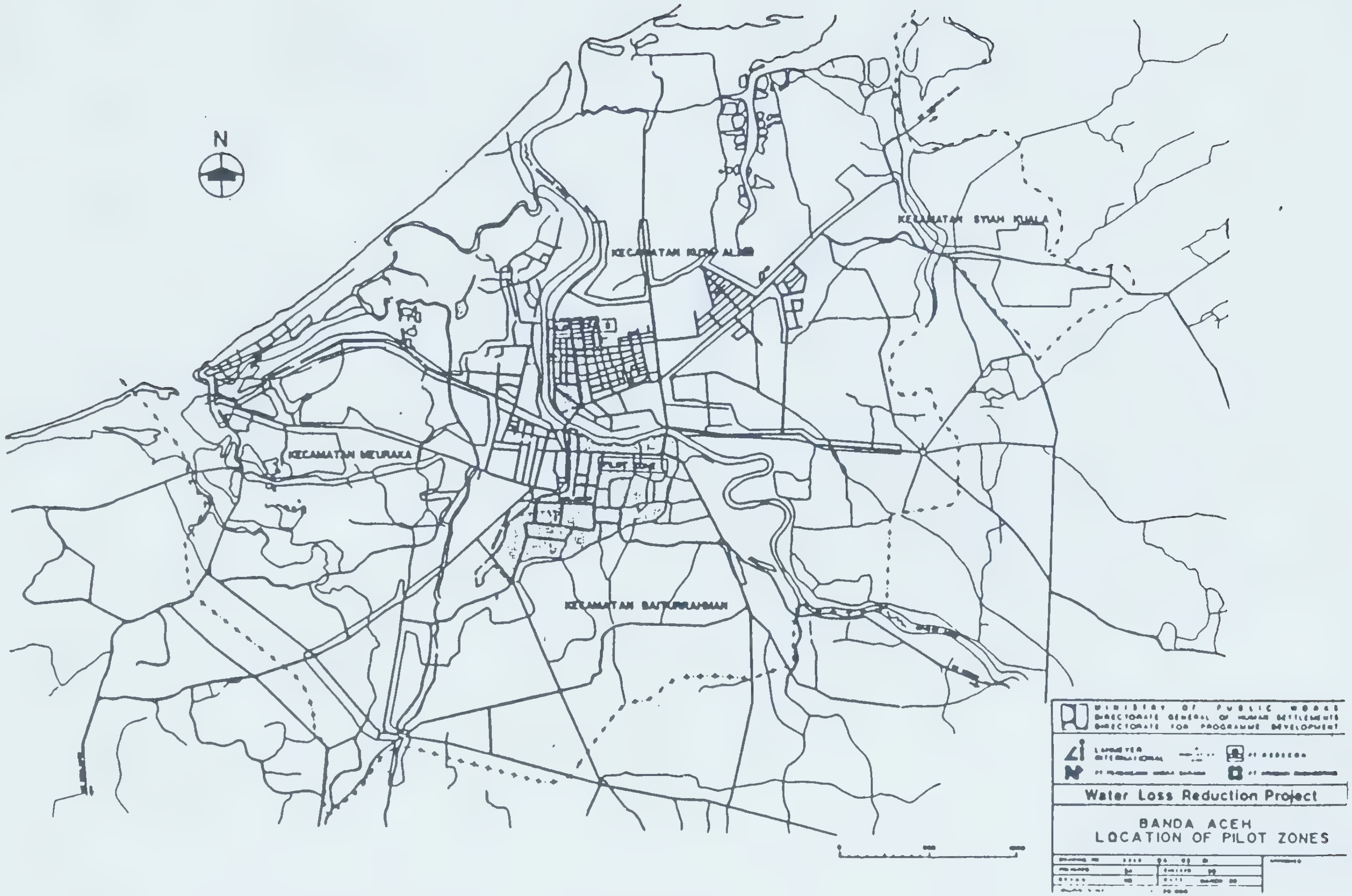


Figure 3.1. Location of Pilot Zones in Banda Aceh

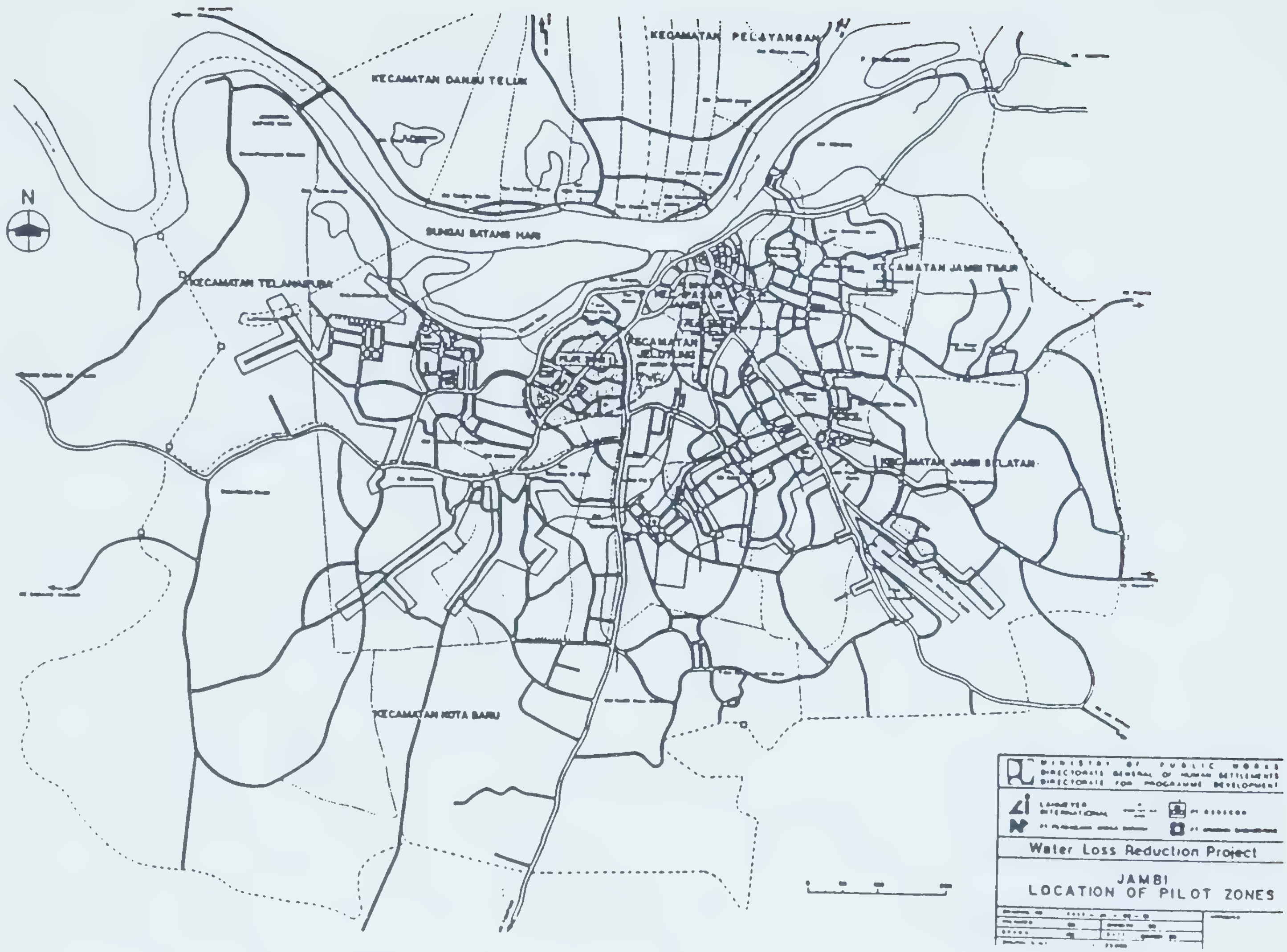


Figure 3.2. Location of Pilot Zones in Jambi

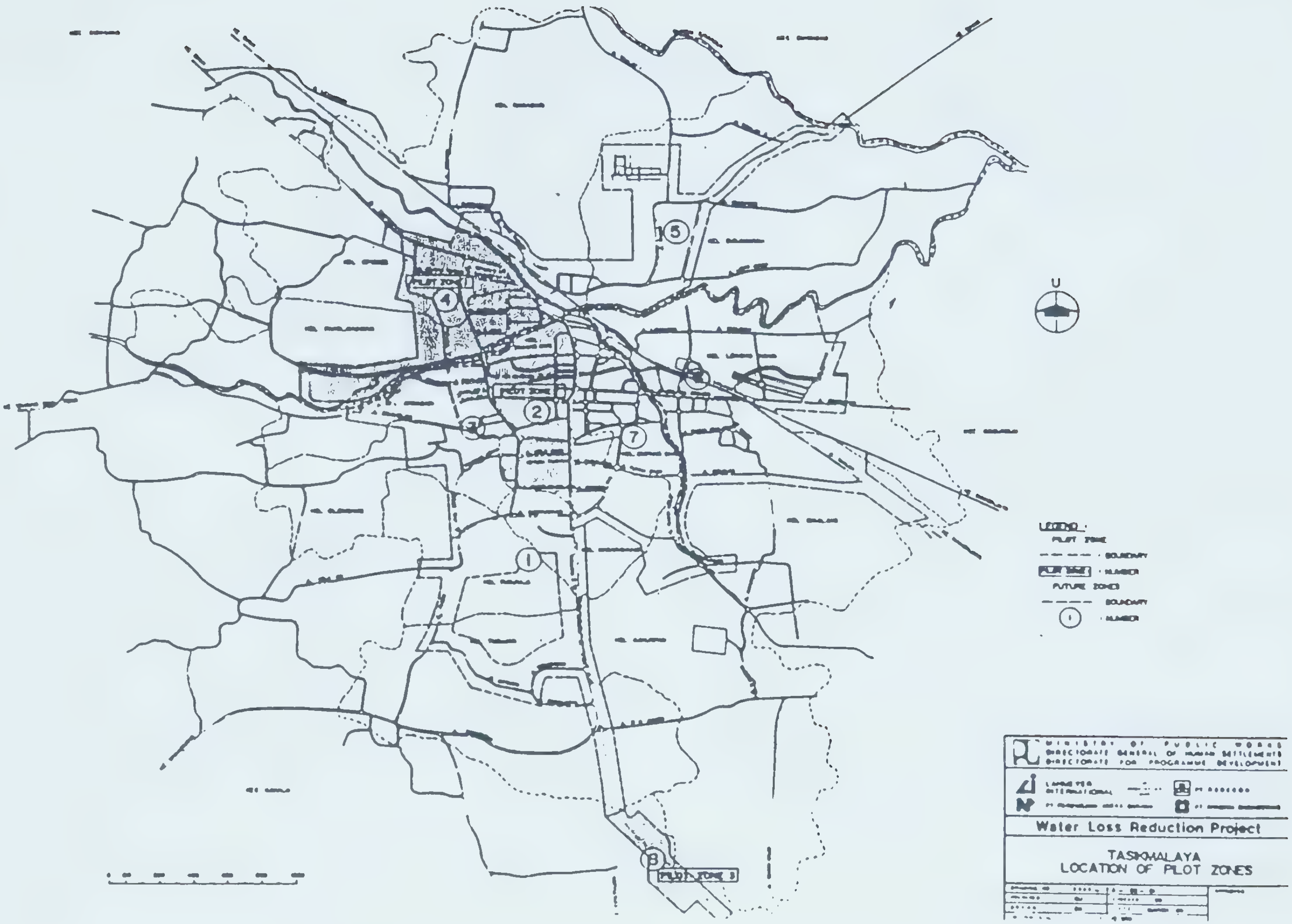


Figure 3.3. Location of Pilot Zones in Tasikmalaya

Figure 3.4. Location of Pilot Zones in Purworejo

Table 3.4. Average Water Production, Distribution and Sales (1988/89)

Description		Banda Aceh	Jambi	Tasikmalaya	Purworejo
Water production	(m^3/d)	26,800	24,306	11,528	9,370
Water distributed	(m^3/d)	24,120	21,390	8,276	9,263
Water sold	(m^3/d)	13,824	15,111	4,591	6,726
Water Loss	(m^3/d)	10,296	6,278	3,685	2,537
	(%)	43	29	44	27

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.1. Consumer and Water Meter Survey

The consumer and water meter survey aimed at the identification of the consumers in the pilot zones of the four towns as well as recording their service connections including water meter, in order to collect the base data required for further assessment of the results from the leak detection program.

A summary of connections, consumer classifications, valves and pipes for the pilot zones in every town is shown in Table 3.5. While information of the condition of water meters in those pilot zones are shown in Table 3.6.

Table 3.5. Consumer Connections, Valves and Pipes at the selected Pilot Zones

Description	Banda Aceh		Jambi		Tasikmalaya		Purworejo	
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 1	Zone 2	Zone 1	Zone 2
# of connection	815	966	1,410	844	482	711	636	359
% of total connection	8	9	10	6	8	11	15	8
Consumer classifications								
- domestic	740	433	1,156	647	395	566	585	337
- commercial	66	458	60	105	72	129	34	14
- industrial	1	8	2	5	1	2	5	3
- social	8	2	8	2	10	8	7	3
- public taps	-	-	11	9	2	3	4	0
- unidentified	-	65	173	76	2	3	1	2
# of valves, including :	40	25	50	30	40	56	33	19
- valves repaired	7	8	12	10	10	18	8	4
- new valves installed	7	13	12	1	5	2	6	5
# of boundary valves	6	7	12	9	3	10	6	5
# of temporary metering points	1	1	1	2	2	1	1	1
Length of pipework (m) including :	17,400	7,830	15,710	7,430	11,980	9,140	8,120	3,690
- 250 mm DI	-	690	-	-	-	-	-	-
- 250 mm AC	-	-	-	-	-	-	300	-
- 200 mm DI	2,970	-	-	-	-	-	-	-
- 200 mm AC	-	-	1,160	-	-	-	700	-
- 150 mm AC	-	-	1,020	-	60	1,000	430	-
- 150 mm PVC	-	790	-	-	-	-	-	-
- 100 mm AC	-	-	290	2,390	4,600	3,450	630	870
- 100 mm PVC	3,790	4,970	1,850	1,560	1,500	-	-	-
- 80 mm AC	-	-	1,790	1,230	3,320	2,570	-	-
- 80 mm PVC	2,480	-	690	1,110	560	-	1,710	830
- 80 mm GI	-	40	-	-	-	-	-	-
Subtotal $\geq \phi$ 80 mm	9,240	6,490	6,800	6,290	10,040	7,020	3,770	1,700
- 50 mm PVC	8,160	310	4,640	610	1,940	2,120	360	180
- 50 mm GI	-	1,030	4,270	530	-	-	-	-
- 40 mm PVC	-	-	-	-	-	-	3,990	1,540
- 40 mm GI	-	-	-	-	-	-	-	270
Subtotal ϕ 50 mm *)	8,160	1,340	8,910	1,140	1,940	2,120	4,350	1,990
% of total length of distribution system	18	8	11	5	13	10	23	10

Source : Lahmeyer Int. & Associates, February 1990[a].

Note : *) In Purworejo pipes of diameter 40 mm have been included

Table 3.6. Water Meter Condition

CONDITION	Banda Aceh		Jambi		Tasikmalaya		Purworejo	
	No	%	No	%	No	%	No	%
Broken	56	3	98	4	62	6	29	3
Buried	14	1	13	1	90	9	3	0
Unreadable	32	2	29	1	21	2	37	4
Satisfactory	1645	94	2091	94	807	83	890	93
Sub Total	1747	100	2231	100	980	100	959	100
No access/not surveyed	34	-	23	-	213	-	36	-
Total	1781	-	2254	-	1193	-	995	-

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.2. Preparation of Pilot Zones

This activity aimed at the preparation of the pilot zones by installing the materials necessary for the isolation of the zones, metering of water flow and pressure, and subdivision of the zones (for the purpose of step testing).

In this step a valve survey was performed in order to locate all valves in the pilot zones and to identify whether their condition was still good or they needed to be cleaned, repaired or replaced. The equipment used for this survey were valve box locator and listening stick.

Beside the repair and replacement of boundary valves and valves for step testing, some minor alterations were also made on the distribution system in order to ensure the adequacy of the condition of the system. For example a pipe had been cut and capped and a new section was installed, or a connection was required between existing pipes in order to increase inadequate pressure. In some cases relocation of service connections was also necessary where these connections were found to be

directly supplied from a transmission or distribution main, or where there was a good reason to move a connection to another zone or step of the step test.

In most cases, metering points, which were required at each zone for flow monitoring purpose, had to be prepared for temporary installation of an insertion flow meter. These metering points will in future be used for permanent monitoring of the particular zone.

3.2.3. Performance of Leak Detection Program

The leak detection program aimed at the detection and repair of the leaks in the pilot zones to an extent achievable in the limited time attributed to the work's schedule. Due to the unreliability of available data and for the purpose of the transfer of knowledge, it was decided that a combination of the two common approaches to determining water system leakage would be performed; water audit and leak detection survey. The term water audit refers to the district flow audit for the respective pilot zones.

In general, the leak detection program comprised the following activities :

- isolation test;
- minimum night flow (MNF) measurement;
- step test; and
- leak detection survey and repairs.

The equipment used for these activities are listed in Table 3.7.

3.2.3.1. Isolation Test

Isolation tests were conducted after the zones had been sufficiently prepared and pressure meters were installed. In some cases final valve checks had to be made

before the isolation test could be successfully performed. The isolation test was started by closing all boundary valves. The main inlet valve was then shut and the pressure gauges installed at strategic points within the zone were monitored. The zone was considered to be satisfactorily isolated when an immediate drop in pressure could be observed.

Table 3.7. List of Equipment for Leak Detection Program

NO.	DESCRIPTION	Unit	QTY	MANUFACTURER	TYPE	COUNTRY OF ORIGIN
	FLOW MEASUREMENT					
1	Insertion Flow Meter	Set	8	Quadrina	Probe flow PT 2S/	Britain
					10BDH/3/MEPD	
2	Tapping Machine for DI & Steel	Set	4	Talbot	No.3	Britain
3	Tapping Machine for AC & PVC	Set	4	Talbot	Taldex III	Britain
	DATA LOGGER					
4	Portable Data Logger	Set	8	Spectrascan	Microlog 2L	Britain
	supporting equipment :					
	a. Pocket Display Unit	Pcs	4	Spectrascan	-	Britain
	b. Logger Function Tester	Pcs	4	Spectrascan	-	Britain
	c. Auto Zero Plug	Pcs	4	Spectrascan	-	Britain
	d. Control Software & Manual	Pcs	2	Spectrascan	-	Britain
	e. Logger/Computer conn. cable	Pcs	4	Spectrascan	-	Britain
	f. Flowmeter Pulse Unit	Pcs	4	Kent	PU 100	Britain
	PRESSURE/LEVEL TRANSDUCER					
5	Pressure Transducer	Set	8	Druck	10 Bar	W. Germany
6	Level Transducer	Set	4	Druck	1 Bar	W. Germany
7	METAL PIPE LOCATOR	Set	4	Radio Detection	RD 400	USA
8	NON-METAL PIPE LOCATOR	Set	4	Fuji	PL 1300	Japan
9	ACCOUSTIC LEAK DETECTOR	Set	4	Fuji	WL 200	Japan
10	LISTENING STICK	Pcs	8	Fuji	LS150/LS100	Japan
11	VALVE BOX LOCATOR	Set	4	Fuji	F-80	Japan
	ACCESSORIES					
12	Measuring Wheel	Unit	4	Fuji	F-20	Japan
13	Pressure Coupling :	Set	8	Vernon Morris	-	Britain
	coupling - male duck	Pcs	8	Druck	-	Britain
	coupling - female Quadrina	Pcs	8	Quadrina	-	Britain
14	Valve Key	Unit	4	Vernon Morris	-	Britain

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.3.2. Minimum Night Flow Measurement

Minimum night flow (MNF) measurements were performed as a means of determining the leakage level in the zones. The minimum night flow in each of the zones was measured in two consecutive nights and had to be repeated in the cases where the results were not satisfactory. One of these results was used as the starting level for measuring the effect of the leak detection program. Another one or two measurements of minimum night flow were recorded after leaks detected were repaired.

All large night consumers were identified and their consumption rates were determined separately by reading their meters at intervals of 10 or 15 minutes.

3.2.3.3. Step Test

Step tests were performed for the purpose of identifying the level of leakage at particular sections or lengths of pipes. The first step test were generally carried out the first night following the minimum night flow test. The results were used to direct the leak detection teams to particular areas of the zone where excessive leakage was likely. After a first round of repairs the second step tests were performed to define the areas where intensive checks had to be made.

The average number of steps per zone was between 10 and 12 with the exception of Tasikmalaya, where almost every pipe segment was considered. The average number of connections and length of pipe work per step varied for each town as shown in Table 3.8.

Table 3.8. Details of Step Testing

Towns	Banda Aceh	Jambi	Tasikmalaya	Purworejo
No. of connections	1,781	2,254	1,193	995
Length of pipe-work (m)	25,230	23,140	21,120	11,810
No. of zones	2	2	2	2
No. of sub-divided zones	-	1	1	-
Average No.of steps per zone	10	12	26	11
Average No. of connections per step	94	94	23	47
Average length of pipe-work per step (m)	1328	964	398	562

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.3.4. Leak Detection and Repair

Leak detection work started following the minimum night flow measurement and first step test. In this case, particular attention was first paid to the backlog of leaks in the whole zone since no leak detection work had previously been done. The techniques used for leak detection work were as follows :

- visual inspection for detection of visible leaks; and
- sonic survey for detection of non-visible leaks.

Detection of visible leaks was conducted at the start of the leakage control works. This is a straight forward operation without the need of additional works and equipment. The operation was normally performed during daytime, but some checks were also undertaken at night when the system pressure was higher.

The detection of non-visible leaks was performed based upon the step test results. Two types of sonic leak detection equipment were used in this survey; listening stick (aquaphone) for the sounding of fittings for leak noise and acoustic leak detector (geophone) for locating or pin-pointing leaks of pipes from the surface. It was performed on those sections of pipelines which were found to have high leakage

levels. Detection works were undertaken during the times of minimum demand when the system pressure was higher.

The leaks found were identified and marked on drawings. Details of the location, pipe size, works and materials required for repair works were noted. Then the repairs were done right away to an extent that materials required were available.

The number of leaks detected as well as the location of the leaks and the pipe diameters and materials are shown in Table 3.9. It shows a considerable difference in the number of leaks detected, varying from 23 in Purworejo to 218 in Jambi. The high difference was recognized as mainly due to the fact that consumer meters in the pilot zones in Tasikmalaya and Purworejo were repaired before this program started, whereas in the two other towns they were considered as part of the repair program. As can be seen from the information about leak locations, the majority of leaks were found at consumer water meters and only some on distribution and service pipes.

From the information about the pipe diameters and materials on which the leaks occurred, it is obvious that most of the leaks happened on diameters of 40 mm and below. While the leak occurrence on materials was found to be depending on the materials prevailing in each town which often reflect the age of the distribution system, since for most newly installed systems the use of plastic pipe (PVC) is preferable except for a very specific local technical reason where galvanized pipe is required.

Table 3.9. Number and Locations of Leaks Detected

	Banda Aceh	Jambi	Tasikmalaya	Purworejo
Number of Connections	1,781	2,254	1,193	995
Length of Pipework	25,230	23,140	21,120	11,810
Leaks Detected :				
- by visual inspection	95	207	5	2
- by sonic survey	10	48	43	21
Total	105	255	48	23
Leaks/1000 Connections	59	113	40	23
Leaks Repaired	96	218	48	23
Leaks Location :				
- Consumer meters	52	86	-	7
- Service pipe	32	82	42	9
- Distribution pipes/joints	12	50	6	7
- Illegal connection	11	17	36	2
Leaks by pipe size & material				
- 40 mm and below				
GI	35	50	6	-
PVC	3	76	33	12
AC	n/a	n/a	n/a	n/a
- 50 mm				
GI	-	2	-	-
PVC	6	3	2	3
AC	n/a	n/a	n/a	n/a
- 80 mm and above				
GI	-	-	-	-
PVC	-	1	1	-
AC	-	-	6	1

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.3.5. Leak Detection Results

From the measurement of minimum night flows before and after leak repairs, the net night flow (in litre/connection/hour) were calculated by deducting 2 litre/connection/ hour as allowance for legitimate consumption during night time. In two towns, Tasikmalaya and Purworejo, where the use on the consumer properties was considered higher, a figure of 4 litre/connection/hour was applied. The reduction achieved in net night flow (in litre/connection/hour) and in leakage (in m^3/day) in the pilot zones of the four towns is shown in Table 3.10.

Table 3.10. Reduction in Net Night Flow and Leakage

Towns	Banda Aceh		Jambi			Tasikmalaya			Purworejo	
Zones Number	1	2	1	2.a	2.b	1.a	1.b	2	1	2
No. of Connections	815	966	1410	560	284	194	288	711	636	359
Net Night Flow (L/conn/hr)										
- Before repair	50.6	86.4	45.7	42.5	23.8	39.1	55.4	72.8	49.3	24.1
- After repair	42.6	77.3	46.3	34.0	19.6	14.2	29.1	42.0	24.7	23.5
- Reduction	8.0	9.1	(0.6)	8.5	4.2	24.9	26.3	30.8	24.6	0.6
Average reduction in NNF	8.6		7.1			28.8			15.9	
Leakage (m^3/day)										
- Before repair	825	1669	-	476	135	152	319	1035	627	173
- After repair	694	1493	-	381	111	55	168	597	314	169
- Reduction	131	176	-	95	24	97	151	438	313	4
Total leakage reduction	307		119			686			317	

Source : Lahmeyer Int. & Associates, February 1990[a].

In calculating the reduction in leakage, an account of the variation in pressure throughout 24 hours was taken. The lower pressure during the day resulted in a lower rate of leakage at that time. The formula used for the calculation of the leakage was described as follows :

LEAKAGE (m^3/day) = NNF x CONN x T x 24/1000

where : NNF = Net night flow in litre/connection/hour

CONN = Number of connections

T = Diurnal pressure variation factor = 20/24 = 0.83

The results indicated the average reduction achieved in the pilot zones. They were compared with the distribution system leakage and were used as the basis for the calculation of the remaining leakage and estimation of possible reduction of unaccounted-for water in each town.

3.2.4. Water Balance and Components of Unaccounted Water

3.2.4.1. Water Balance for Four Representative Towns

A water balance for each of the four representative towns was established with the aim of determining the components of unaccounted water. The figures determined as unaccounted-for water and particularly non-physical losses and distribution system leakage (physical losses) were used later as the basis for estimating the possible reduction of the losses. The water balance evaluation and the estimated components of unaccounted-for water for the four towns are shown in Table 3.11

Installation of an insertion flow meter on the distribution main of each particular town was also performed for the purpose of checking the accuracy of the existing water meter. The flow was then monitored for some days and the results were compared with flow recorded at the existing meter. Any underestimation of volumes are indicated in Table 3.11 line (2).

Table 3.11. Components of Unaccounted-for Water in the 4 Selected Towns

	Banda Aceh		Jambi		Tasikmalaya		Purworejo	
	m3/d	%	m3/d	%	m3/d	%	m3/d	%
1. Water Distributed (*)	24,120	100.0	21,390	96.0	8,276	59.9	9,263	100.0
2. Underestimation of Vol. Distributed	-	-	890	4.0	5,534	40.1	-	-
3. Total Vol. Distributed	24,120	100.0	22,280	100.0	13,810	100.0	9,263	100.0
4. Metered Consumption	13,145	54.5	14,256	64.0	5,031	36.5	6,726	72.6
5. Unaccounted-for Water :	10,975	45.5	8,024	36.0	8,779	63.5	2,537	27.4
- Overestimation of Vol. Distributed	2,770	11.5	-	-	829	6.0	370	4.0
- Consumer Meter Errors	390	1.5	445	2.0	207	1.5	140	1.5
- Illegal Connections	600	2.5	555	2.5	414	3.0	45	0.5
- Administrative Errors	1,200	5.0	890	4.0	621	4.5	90	1.0
- Unmetered Authorized Usage	480	2.0	110	0.5	0	0.0	0	0.0
6. Sub-total (Non-physical Losses)	5,440	22.5	2,000	9.0	2,071	15.0	645	7.0
7. Distribution System Leakage (Physical Losses)	5,535	23.0	6,024	27.0	6,708	48.5	1,892	20.4

Source : Lahmeyer Int. & Associates, February 1990a.
Note : (*) Last 12 months until July '89

A considerable underestimation of about 40 percent of the water distributed was recorded in Tasikmalaya. It was found to happen due to a defect in main water meter. This meter had been replaced and new reading was taken as a basis the calculation.

Analysis and calculation of the components of non-physical losses were made based upon the findings from field activities and reasonable assumptions after taking into account the local conditions. The subtotal of non-physical losses is shown in Table 3.11 on line (6). The remaining unaccounted-for water is attributed to distribution system leakage (or physical losses) as shown in the same table on line (7).

3.2.4.2. Water Balance for 16 Remaining Towns

Water balances for the other 16 towns were calculated based upon data obtained during field investigation and some obligatory field checks. However, the breakdown of the unaccounted-for water was not possible due to the unavailability of data.

A summary of distribution system data and water balance for all 20 towns, including the four representative towns, is shown in Table 3.12.

Table 3.12. Summary of Distribution System Data and Water Balance for 20 Towns

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
TOWN	System capacity (L/s)	No. of service connections	Dist. pipe length (m) > 50 mm	Tertiary pipe length (m) < 50 mm	1989 net production (m3/year)	'89 metered consumption (m3/year)	Unaccounted-for Water		Ave annual net prod. (L/s)
							(m3/year)	(%)	
Banda Aceh	300	10,786	88,820	108,000	8,803,800	4,797,925	4,005,875	45.5	279
Jambi	300	14,733	100,900	48,100	8,132,200	5,203,440	2,928,760	36.0	258
Tasikmalaya	175	6,230	75,430	16,340	5,040,650	1,836,315	3,204,335	63.5	160
Purworejo	112	4,358	24,080	11,250	3,380,995	2,454,990	926,005	27.4	107
Langsa	46	3,899	69,830	27,802	1,272,249	912,073	360,176	28.3	40
Pangkalan Brandan	40	2,434	19,900	16,800	1,062,205	689,165	373,040	35.1	34
Binjai	46	1,613	20,191	4,739	736,970	491,411	245,559	33.3	23
Tebing Tinggi	60	2,311	30,157	40,172	1,285,516	780,842	504,674	39.3	41
Kisaran	40	2,982	59,188	n/a	1,131,150	832,579	298,571	26.4	36
Rantau Prapat	40	2,790	21,000	12,700	1,031,371	784,447	246,924	23.9	33
Padang Sidempuan	78	2,796	42,600	30,300	2,053,560	1,002,755	1,050,805	51.2	65
Pakanbaru	280	10,090	110,700	76,500	4,624,172	3,439,352	1,184,820	25.6	147
Pangkal Pinang	88	3,378	21,200	n/a	656,687	470,878	185,809	28.3	21
Baturaja	55	3,619	28,400	17,000	1,783,172	1,066,964	716,208	40.2	57
Serang	89	4,544	61,600	21,700	2,819,310	2,107,834	711,476	25.2	89
Bekasi	89	8,453	84,600	88,500	2,629,362	1,773,005	856,357	32.6	83
Garut	85	3,546	18,500	4,100	2,441,666	1,196,334	1,245,332	51.0	77
Cilacap	200	3,900	87,500	4,800	1,963,657	1,243,346	720,311	36.7	62
Purwokerto	134	8,337	107,100	131,800	4,428,760	3,094,242	1,334,518	30.1	140
Magelang	390	9,948	89,500	87,800	12,039,896	7,016,601	5,023,295	41.7	382

Source : Lahmeyer Int. & Associates, August 1990.

3.2.5. Estimated Reduction in Unaccounted Water

The potential for water loss reduction in the four representative towns was estimated using the results of leak detection program in the respective pilot zones as the basic for calculation.

If the reduction in leakage achieved in the pilot zones of the towns was assumed to be the average reduction in distribution system leakage for the whole town, the total reduction in distribution system leakage for each town can be calculated and summarized as shown in Table 3.13 below. Line (1) of the table indicates the existing distribution system leakage as calculated in Table 3.11, while line (2) shows the average reduction in leakage which was derived from the figures shown in Table 3.10.

Table 3.13. Reduction in Distribution System Leakage in the Four Representative Towns

TOWNS	Description	Leakage Level		
		m^3/day	L/conn./hr	(%)
Banda Aceh	(1) Distribution system leakage	5,535	25.7	23.0
	(2) Reduction in leakage	1,859	8.6	7.7
	(3) Remaining leakage	3,676	17.1	15.3
Jambi	(1) Distribution system leakage	6,024	20.4	27.0
	(2) Reduction in leakage	2,092	7.1	9.4
	(3) Remaining leakage	3,932	13.3	17.6
Tasikmalaya	(1) Distribution system leakage	6,708	53.7	48.5
	(2) Reduction in leakage	3,588	28.8	26.0
	(3) Remaining leakage	3,120	24.9	22.5
Purworejo	(1) Distribution system leakage	1,892	21.7	20.4
	(2) Reduction in leakage	1,386	15.9	15.0
	(3) Remaining leakage	506	5.8	5.4

Source : Lahmeyer Int. & Associates, February 1990 [a].

For the possibility of reducing the non-physical losses, it was assumed that due to administrative measures supported by organizational assistance these losses could generally be limited to 6 percent as follows (Lahmeyer Int. & Associates, February 1990[a].) :

- error in volume distributed	0.5 percent
- consumer meter error	1.5 percent
- illegal connections	2.0 percent
- administrative errors	2.0 percent
- unmetered authorized usage	0.0 percent
Total non-physical losses =	6.0 percent

Based on further analyses of physical characteristics and the results of leak detection program, a realistic approach to the possible reduction in losses, both physical (distribution system leakage) and non-physical losses, was made as shown in Table 3.14. The situation of unaccounted-for water in each of the four towns before this project is repeated in the first column. The reduction achieved after the pilot project (leak detection program) is reflected in the second column, where there was no reduction of the non-physical losses. The possible reduction of both losses after implementation of this project is indicated in the third column. It was assumed that the non-physical losses could generally be reduced to 6 percent, whereas an allowance for further reduction up to 13 percent of the distribution system leakage, dependent on the distribution system leakage before the start of the project and the reduction achieved during the leak detection program in the pilot zones, was justified based upon consideration of the fact that the leak detection program was executed in a very limited time and not all of the leaks found were repaired. On the contrary, a more realistic figure for the reduction in distribution system leakage for Purworejo was applied.

Table 3.14. Possible Reduction of Unaccounted-for water for the 4 Representative Towns.

TOWN	Description	Leakage Level (%)		
		(1) Before Project	(2) After Pilot Project	(3) After Implementation
Banda Aceh	Non-physical losses	22.5	22.5	6.0
	Distribution system leakage	23.0	15.3	14.0
	Unaccounted-for water	45.5	37.8	20.0
Jambi	Non-physical losses	9.0	9.0	6.0
	Distribution system leakage	27.0	17.6	14.0
	Unaccounted-for water	36.0	26.6	20.0
Tasikmalaya	Non-physical losses	15.0	15.0	6.0
	Distribution system leakage	48.5	22.5	18.0
	Unaccounted-for water	63.5	37.5	24.0
Purworejo	Non-physical losses	7.0	7.0	6.0
	Distribution system leakage	20.4	5.4	11.0
	Unaccounted-for water	27.4	12.4	17.0

Source : Lahmeyer Int. & Associates, February 1990[a].

From Table 3.14 above it can be concluded that after implementation of the project the unaccounted-for water will be reduced to 20 percent in Banda Aceh and Jambi, and to 17 percent and 24 percent in Purworejo and Tasikmalaya, respectively. The percentage of unaccounted-for water for Tasikmalaya could not be expected to reach 20 percent during the implementation of this project due to the existing very high distribution system leakage.

In the attempt to estimate the possible reduction of the unaccounted-for water for the other 16 towns, it was concluded that these results, could not be extrapolated for those remaining towns. Any statement about the possible reduction of unaccounted-for water had to be based on the actual water balance, i.e. the components of unaccounted water, which was not established for the 16 towns due to limited time of the study. It was therefore assumed to define the target for the reduction of unaccounted-for water for these towns with 20 percent, 6 percent for maximum non-

physical losses and 14 percent as maximum permissible distribution system leakage. This target would also match with recent guide-lines for water supply sub-sector development program, according to which the permissible level of unaccounted-for water is 20 percent.

3.2.6. Concept for Program Implementation

A concept for program implementation covering technical and institutional aspects was developed based upon a thorough evaluation of typical major characteristics of the towns and the achievement of leakage reduction in the pilot zones. The program implementation is intended to be performed by each water utility with the equipment and materials as well as technical assistance provided by the project. In this case the consultant would assist the water utilities in the execution of the work program for only the first two or three zones, after which each water utilities should be able to continue on the remaining zones by itself. The concept comprises the following steps :

1. general preparations
   - 1.1. institutional development of water utility
   - 1.2. preparation of detailed drawings (mapping)
   - 1.3. installation of master flow meters
2. zone establishment
   - 2.1. preparatory works
   - 2.2. valve and pipe location survey
   - 2.3. consumer and water meter survey
   - 2.4. installation of materials
   - 2.5. repair / replacement of water meters

3. leak detection and repair program
    3.1. isolation test
    3.2. leak detection survey
    3.3. leak repairs
    3.4. evaluation of results

General preparations would be required prior to the start of zone establishment since the project will generally be implemented zone after zone. It should be noted that prior to the commencement of project implementation, a period for procurement of the required equipment and materials has to be considered.

Zone establishment and the leak detection program will be executed one after the other, following the same sequence of activities for each zone.

3.2.6.1. General Preparations

The general preparations must be started well ahead of the zone establishment of the individual zones and comprise primarily institutional development of water utility, mapping of the whole distribution system, and installation of master flow meters to monitor the total flow into the distribution system.

The institutional development is considered as an essential and constituent part of the program as it is needed for the control of non-physical losses. There are strong indications that by implementation of the institutional measures, particularly boosting of data processing and meter maintenance service, the non-physical losses will be reduced to the target level. The institutional components would comprise the following measures :

1. development of corporate objectives and targets, as well as review of planning and performance monitoring;

2. introduction of data processing (computerization) including hardware supplements;
3. development of a meter maintenance service;
4. set-up of an "operations and leakage control center" for the monitoring of network performance as well as the steering of leak detection and repair activities;
5. set-up of a "leak detection group" for the execution of leak detection survey and repairs; and
6. review of consumer relations policy and development of an integrated public education program.

Mapping of the distribution system needs to be done by the Water Utilities Planning Division and should be started at the earliest possible date to be available at the commencement of zone establishment. The drawings should be prepared at a scale of 1:1000 and should contain all available data at the time of preparation such as lay out of the distribution system, valve and fire hydrant locations as well as pipe diameters and materials. For this purpose, general guide-lines for the preparation of standard drawings were issued.

The drawings should be updated and completed zone wise during the valve and pipe location survey in each zone. They will then be used for the consumer and meter survey to locate the individual consumers in each zone as well as for step testing during the leak detection survey. The drawings shall later on be kept in the new operation and leakage control center for use in the future routine leakage control operations.

Installation of master flow meters are required for those water utilities that have no flow meter at the main distribution pipe. For those towns which already had one, either calibration or replacement of the installed flow meter needs to be done since none of them had been calibrated in the last five years or since they were installed.

3.2.6.2. Zone Establishment

The activities during this stage aimed at the division of distribution network into zones and preparation of the zones including the installation of materials necessary for the execution of the leak detection program. All preparatory works in connection with zone establishment should have been done during the pipe and valve survey.

To facilitate the estimate of materials and staff input for all works related with implementation of the project, average zone parameters for zoning of the distribution network, as shown in Table 3.15, had been developed using the average characteristics of the pilot zones. Based on these criteria and further evaluation of local distribution system conditions, number of zones for each of the towns was established and are shown in combined with the project cost estimate in Section 3.3.3 (Table 3.18).

Table 3.15. Average Zone Parameters

Parameter	Average	Acceptable Range
Number of Connections	750	500 to 1,000
Number of metering points	2	1 to 2
Total Number of Valves	35	20 to 50
Length of Pipe work (m)	10,000	5,000 to 15,000

Source : Lahmeyer Int. & Associates, April 1990.

The valve and pipe location survey will be using the relevant equipment, described in Section 3.2.6.4, for the following purposes :

- updating of the maps prepared earlier by indicating all valves and pipe locations, so an exact layout drawing in the scale 1:1000 will be available for the relevant zone.

- recording of the condition of valves, location of service connections and any pipe work that is required for zone preparation. Based on this information, the detailed material requirements and scope of works for zone establishment will then be prepared.

The same activities as performed in the pilot zones were recommended for the consumer and water meter survey; including :

- collection of data comprising consumer information, water meter data and condition and length of consumer connections,
- recording of all details like street names and house numbers and identification of the consumers as well as location of consumer connection and water meter.

The information of the consumers will then be evaluated and conclusions will be drawn for water meter replacement and relocation of consumer connections.

For the purpose of preliminary cost estimate, the required materials and water meter replacement for the other 16 towns could be extrapolated from the estimated quantities shown in Table 3.16, which were concluded from those provided and installed in the pilot zones of the four representative towns.

Table 3.16. Estimated Materials for Zone Preparation per Zone

Description	Unit	Quantity
Valves : - newly installed	Number	5 to 10
- repaired	Number	5 to 15
Metering points	Number	2
Relocation of consumer connections	Number	25 to 50
Pipe-work	Meter	50 to 150

Source : Lahmeyer Int. & Associates, February 1990[a].

3.2.6.3. Leak Detection and Repair Program

The leak detection program aimed at the detection of the distribution system leakage after all preparation works have been executed and the particular zone can be isolated. The leak detection equipment described in Section 3.2.6.4 was a prerequisite for the successful of the program.

Since there has been no leakage control done before in the zones, it was recommended to start with the repair of the backlog of leaks. For this purpose the minimum night flow needs to be measured and, thereafter, the leak detection team will work through the whole zone in an effort to reduce the backlog of leaks. The technique used to find the leaks will mainly be visual inspection.

The further steps recommended for the implementation of leak detection program will generally comprise the following activities :

- isolation test;
- minimum night flow measurement and subsequent step testing for identification of the location of the leaks;
- leak detection survey using sonic equipment for pin-pointing the location of the leaks;
- leak repair works and preliminary evaluation of results after repairs; and
- repetition of above activities, except for the isolation test, until the goal is reached.

The sonic leak detection equipment generally applied will be the listening stick for sounding of fittings and the acoustic leak detector for locating leaks of pipes. A standard form prepared earlier will be used to note details of the type and location of the leaks, which will then be used for the repair of the leaks.

3.2.6.4. Leak Detection Equipment

The list of equipment which was recommended for the future program is shown in Table 3.17 with the quantities indicated, which were considered appropriate for each category of water utility. The classification of water utility and the type and number of equipment required were concluded from experience in the pilot zones and evaluation of distribution system characteristics, financial situation and personnel available in each town. From the viewpoint of application, these equipment can be divided into the following groups :

1. logging equipment for flow and pressure measurements;
2. valve and pipe location equipment; and
3. sonic leak detection equipment.

The data logger including accessories and software for the computer has proven to be a useful tool for monitoring of the flow and pressure. It will be used in the future to record flow of the permanently installed water meters (using a pulse unit) and pressure at the metering points or by means of hydrants, where available. During the leak detection program the data logger will be applied for the measurement and recording of the minimum night flows and step testing. This equipment, is only recommended for the larger towns.

The valve and pipe location equipment will be required in total and will be used for the activities in connection with zone preparation, while the listening sticks and acoustic leak detector are required for control of the functioning of valves and locating leaks, respectively.

Table 3.17. List of Leak Detection Equipment for Future Leakage Control Program

DESCRIPTION	Unit Price Rp. x 1,000	Water Enterprise with no. of connections					
		> 8,000		4,000 - 8,000		< 4,000	
		Qty	Sub total xRp.1,000	Qty	Sub total xRp.1,000	Qty	Sub total xRp.1,000
- DATA LOGGER (*)							
Model SPECTRASCAN Microloge 2 L	20,500	4	82,000	3	61,500	-	-
- PRESSURE TRANSDUCER							
Model DRUCK 10 - bar	2,000	4	8,000	2	4,000	-	-
- LEVEL TRANSDUCER							
Model DRUCK 1 - bar	3,500	2	7,000	1	3,500	-	-
- PULSE UNIT for Water Meter							
Model KENT PU 100	1,000	4	4,000	3	3,000	-	-
- PRESSURE COUPLING (for Hydrants)							
Model VERNON MORRIS	500	4	2,000	2	1,000	-	-
- Metal Box Locator - model FUJI F - 80	1,500	2	3,000	2	3,000	2	3,000
- Metal Pipe Locator - model RD - 400	7,500	2	15,000	1	7,500	1	7,500
- Non-Metal Pipe Locator - model Fuji PL130	13,000	2	26,000	-	-	-	-
- Measuring Wheel - model FUJI F-20	1,000	2	2,000	2	2,000	2	2,000
- Valve Key - model VERNON MORRIS	500	2	1,000	2	1,000	2	1,000
- LISTENING STICK							
Model FUJI 1.0 m & 1.5 m	500	4	2,000	4	2,000	4	2,000
- ACOUSTIC LEAK DETECTOR							
Model FUJI WL - 200	4,000	2	8,000	1	4,000	1	4,000
- Local Transport Allowance	lumpsum	-	3,000	-	2,000	-	500
TOTAL COST (x Rp. 1,000)			163,000		94,500		20,000

Source : Lahmeyer Int. & Associates, August, 1990.

Note : (*) = Including Accessories

Based on 1989 price with exchange rate US $ 1.00 = Rp. 1,720.00

3.3. PROJECT COST

3.3.1. General

The cost estimate for the implementation of water loss reduction project in the 20 towns had been made after the scope of the project and implementation schedule for each of the towns was prepared.

In general, the scope of water loss reduction project follows the concept for program implementation described in Section 3.2.6 and will be supported by rehabilitation works, which comprise the rehabilitation of distribution and tertiary pipes and water meter relocation. These additional measures include pipe repair works at either distribution mains or tertiary pipes which are not properly installed as well as repair of leaks outside of the zones and repair works at reservoirs. While water meter relocation is required in accordance with the standard service connection and water meter installation which was prepared in order to make all meters accessible and to avoid manipulations by consumers. It is basically expected that at the end of the project, each water utility in those towns will have a water supply system which will fulfill the requirements for future system operation and leakage control work such as :

- complete as-built drawings;
- file of all pipes and armatures installed;
- reliable water flow and consumption measurements;
- all consumer meters are accessible and in good condition;
- each distribution zone controllable ; so that the water utility can directly react if due to leaks the water consumption in any zone rises above the acceptable level;
- administrative errors and inadequate procedures under control;

- repair works easily to be allocated due to the availability of as-built maps;
- maintenance can be executed properly and periodically due to existing file of material condition and age; and
- integrated future planning can be executed easily due to detailed as-built drawings.

In order to expedite the execution of the project and to minimize the cost required for consulting services, the implementation schedule was prepared using an approach that the water loss reduction project will be undertaken simultaneously with priority is given to those four representative towns. In general, the entire project will be completed after 50 months, in which the consultant services for training and supervision will be required during the first 20 months.

3.3.2. Components of Project Implementation Cost

The cost estimate of the project was calculated in terms of local currency (Rp. or Rupiah currency) based on the implementation schedule and scope of the project developed earlier, and 1989 price. The components of the project cost can generally be divided into four groups as follows :

1. investment cost of the leakage control program :

   a. equipment / materials ;

      - master flow meters,
      - water meter replacement,
      - leak detection equipment,
      - valves,
      - zone metering points,
      - pipe works,

- service connection relocation, and
- leak repair works.

b. civil works ;

- installation of master flow meters,
- installation of valves,
- zone metering points,
- pipe works,
- service connection relocation, and
- leak repair works.

2. cost of rehabilitation works ;
   - rehabilitation of distribution and tertiary pipes, and
   - Water meter relocation.
3. consulting and water utility internal costs ;
   - supervision costs (consulting services), and
   - water utility internal costs.
4. cost of institutional package.

The cost for consulting services is required for training and supervision of the project implementation in the first three zones of each town, including the institutional development program. While the water utility internal costs cover all expenses that need to be provided by the water utilities, such as for operation cost and incentives, for their staff who involve in the project implementation.

The cost of institutional package includes all tools and software required for the institutional strengthening program in relation with the reduction and control of non-physical losses.

3.3.3. Cost Estimates

The total base costs of the project for every town were derived from each cost component as mentioned earlier and are summarized in Table 3.18. The base year for cost estimate is 1989.

Table 3.18. Summary of Project Investment Base Costs

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
TOWN	No. of Service Connection	No. of Zones	Cost of Leakage Control Program x Rp. 1,000	Cost of Rehabilitation Works x Rp. 1,000	Consulting Costs x Rp. 1,000	Water Utilities Internal Costs x Rp. 1,000	Institutional Package x Rp. 1,000	Total Base Cost Estimate x Rp. 1,000
Banda Aceh	10,786	12	521,140	774,733	375,000	105,000	63,000	1,838,873
Jambi	14,733	13	514,287	731,350	370,000	100,000	43,000	1,758,637
Tasikmalaya	6,230	8	298,505	511,215	215,000	60,000	53,000	1,137,720
Purworejo	4,358	9	218,518	534,689	160,000	45,000	63,000	1,021,207
Langsa	3,899	5	142,395	670,120	105,000	30,000	73,000	1,020,515
Pangkalan Brandan	2,434	4	89,399	221,075	65,000	20,000	73,000	468,474
Binjai	1,613	4	81,054	130,940	60,000	15,000	73,000	359,994
Tebing Tinggi	2,311	5	102,425	240,925	75,000	20,000	73,000	511,350
Kisaran	2,982	6	109,491	335,400	80,000	20,000	73,000	617,891
Rantau Prapat	2,790	6	100,536	278,800	70,000	20,000	73,000	542,336
Padang Sidempuan	2,796	6	119,091	362,753	85,000	25,000	73,000	664,844
Pakanbaru	10,090	14	412,657	654,450	295,000	80,000	73,000	1,515,107
Pangkal Pinang	3,378	4	60,774	155,950	45,000	15,000	73,000	349,724
Baturaja	3,619	6	105,081	359,700	75,000	20,000	63,000	622,781
Serang	4,544	8	220,828	352,260	160,000	45,000	43,000	821,088
Bekasi	8,453	10	223,370	609,190	160,000	45,000	43,000	1,080,560
Garut	3,546	5	97,535	284,235	70,000	20,000	73,000	544,770
Cilacap	3,900	8	155,603	501,300	110,000	30,000	73,000	869,903
Purwokerto	8,337	10	293,405	437,100	210,000	60,000	73,000	1,073,505
Magelang	9,948	12	262,552	5,554,100	190,000	55,000	63,000	6,124,652

Source : Lahmeyer Int. & Associates, August 1990.
Note : Exchange Rate (1989) US $ 1.00 = Rp. 1,720.00

3.4. FINANCIAL ANALYSIS AND FINAL RESULTS

3.4.1. Financial Analysis

Financial analysis for each of the towns was prepared at the project level using nominal cost as payable by the water utilities. It was done to determine the Financial Internal Rate of Return (FIRR) of the project for a given tariff level. The assumption used in the analysis can be summarized as follows :

1. Time period for evaluation is 1990 to 1995 in accordance with the project implementation schedule
2. Total project cost was determined through the following steps :
   a. the total estimated expenditures as shown in Table 3.18, excluding rehabilitation costs, were transformed into current prices for the period 1990 to 1995 by escalating the annual proportions of each investment item. The escalation rates used are ;

      Local currency : 8 percent for 1990 to 1995

      Foreign currency : 5.3 percent in 1990 and 4.1 percent thereafter

   It should noted here that the cost of rehabilitation works was not taken into account in the total project cost used for the FIRR analysis, due to the following considerations :

   - the expected reduction in unaccounted-for water rate can be achieved without rehabilitation works (through leakage control and institutional development program).
   - the rehabilitation works are recommended, however, to bring the water supply scheme to a proper technical standard, supporting the water utilities

to keep or even decrease in future the reduced acceptable rate, but are not directly related to a reduction of the water losses.

- there was a possibility that the rehabilitation works would be incorporated into another program under financial assistance from different sources. Therefore it was preferable to make a pure project analysis to discern the financial impacts of the water loss reduction project alone with regard to the tariff level and margins for financing.

b. price contingencies were applied to the base cost, excluding institutional package, after adding 10 percent physical contingencies defined as possible increase in costs by physical conditions which adversely affect the construction or installation of the works and which could not be foreseen at the planning and design stage.

c. finally, to total base cost, plus physical contingencies and plus price contingencies, 10 percent value added tax (VAT) applicable to the project were added to arrive at total project cost.

3. Project benefits

Calculation of project benefits was made based on the following two possible sources of benefits stemming from the implementation of the project :

a. additional water available for sale due to the reduction of the percentage of unaccounted-for water. This is the case for the period when demand for water is higher than the water produced. The additional water available for sale was then valued with the average tariff and entered the calculation as incremental benefit during the period.

b. saving in production cost, as due to the implementation of the project less volume of water have to get produced according to demand forecast. This is the case if the net production capacity exceeds the existing demand. In this

case, the demand forms the basis for calculating the necessary production with and without the water loss reduction project. The difference, i.e. not produced water due to the project was then multiplied with the cost price and entered as benefits in the analysis.

In the case that tariff adjustment is possible and needs to be introduced in order to recover the investment and operating cost of the project, the financial analysis for the new proposed tariff has also been done. The FIRRs for each town, both for the existing and proposed tariff, are shown in Table 3.19.

3.4.2. Final Results of the Study

The analysis of financial internal rate of return forms as the basis for determination of the feasibility of the project. Since the implementation of the project will be financed through a loan from the Asian Development Bank in which case the borrower will not be the water utilities but the Government of Indonesia, which will bear the foreign exchange risk, therefore the following financing conditions, established by the Government for providing loans to a public utility, were applied :

- Interest rate 9 percent
- Grace period 5 years
- Terms 20 years (including grace period)

Based upon the financial analysis and the above financing conditions, it was finally concluded that the project was considered feasible only for 14 out of the 20 towns, that is for those whose FIRR is more than 9 percent.

Table 3.19. Summary of Financial Analysis Results

Column 1	Column 2	Column 3	Column4	Column 5	Column 6	Column 7	Column 8
	Banda Aceh	Jambi	Tasikmalaya	Purworejo	Langsa	Pangkalan Brandan	Binjai
Number of Connection	10,786	14,733	6,230	4,358	3,899	2,434	1,613
Population Served	60,250	92,895	27,895	21,912	20,484	14,574	7,098
Water Supply Source	Non-spring	Non-spring	Spring	Non-spring	Non-spring	Non-spring	Non-spring
Average Unaccounted-for Water (%):							
- existing	45.5	36.0	63.5	27.4	28.3	35.1	33.3
- after program	20.0	20.0	24.0	17.0	20.0	20.0	20.0
Project Cost (x Rp. 1,000) :							
- Base Cost	1,064,140.0	1,027,287.0	626,505.0	486,518.0	350,395.0	247,399.0	229,054.0
- Physical Contingencies	100,114.0	98,428.7	57,350.5	42,351.8	27,739.5	17,439.9	15,605.4
- Price Contingencies	59,997.0	59,195.3	34,378.0	25,590.0	17,284.0	10,815.0	9,597.0
- Value Added Tax	116,125.1	114,191.1	66,523.4	49,146.0	32,241.9	20,265.4	18,125.6
Grand Total Leak Control Program	1,340,376.1	1,299,102.1	784,756.9	603,605.8	427,660.4	295,919.3	272,382.0
- Rehabilitation Cost	774,733.0	731,350.0	511,215.0	534,689.0	670,120.0	221,075.0	130,940.0
Total Leak Control + Rehabilitation	2,115,109.1	2,030,452.1	1,295,971.9	1,138,294.8	1,097,780.4	516,994.3	403,322.0
Water Tariff and FIRR :							
- Existing Average Tariff (Rp/m3)	282	328	260	194	257	259	237
- FIRR (%)	37.92	46.05	56.40	10.21	2.59	13.45	2.92
- Proposed Tariff (Rp/m3)	282	328	260	194	257	259	237
- FIRR (%)	37.92	46.05	56.40	10.21	2.59	13.45	2.92

Source : Lahmeyer Int. & Associates, August 1990.
Note : 1989 Exchange Rate - US $ 1.00 = Rp. 1,720.00

Table 3.19. Summary of Financial Analysis Results (Cont'd)

Column 1	Column 9	Column 10	Column 11	Column 12	Column 13	Column 14	Column 15
	Tebing Tinggi	Kisaran	Rantau Prapat	adang Sidempu	Pakanbaru	Pangkal Pinang	Baturaja
Number of Connection	2,311	2,982	2,790	2,796	10,090	3,378	3,619
Population Served	13,380	16,997	10,350	12,382	51,403	7,311	18,448
Water Supply Source	Non-spring	Non-spring	Non-spring	Spring	Non-spring	Non-spring	Non-spring
Average Unaccounted-for Water (%):							
- existing	39.3	26.4	23.9	51.2	25.6	28.3	40.2
- after program	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Project Cost (x Rp. 1,000) :							
- Base Cost	270,425.0	282,491.0	263,536.0	302,091.0	860,657.0	193,774.0	263,081.0
- Physical Contingencies	19,742.5	20,949.1	19,053.6	22,909.1	78,765.7	12,077.4	20,008.1
- Price Contingencies	12,092.0	12,800.0	11,638.0	13,960.0	47,035.4	7,246.4	12,131.0
- Value Added Tax	22,926.0	24,324.0	22,122.8	26,596.0	91,345.8	14,009.8	23,222.0
Grand Total Leak Control Program	325,185.5	340,564.1	316,350.4	365,556.1	1,077,803.9	227,107.6	318,442.1
- Rehabilitation Cost	240,925.0	335,400.0	278,800.0	362,753.0	654,450.0	155,950.0	359,700.0
Total Leak Control + Rehabilitation	566,110.5	675,964.1	595,150.4	728,309.1	1,732,253.9	383,057.6	678,142.1
Water Tariff and FIRR :							
- Existing Average Tariff (Rp/m3)	293	242	215	120	240	153	214
- FIRR (%)	43.33	-6.45	-8.17	20.81	8.09	10.13	27.78
- Proposed Tariff (Rp/m3)	293	242	215	200	240	191	214
- FIRR (%)	43.33	-6.45	-8.17	39.35	8.09	22.82	27.78

Source : Lahmeyer Int. & Associates, August 1990.

Note : 1989 Exchange Rate - US $ 1.00 = Rp. 1,720.00

Table 3.19. Summary of Financial Analysis Results (Cont'd)

Column 1	Column 16	Column 17	Column 18	Column 19	Column 20	Column 21
	Serang	Bekasi	Garut	Cilacap	Purwokerto	Magelang
Number of Connection	4,544	8,453	3,546	3,900	8,337	9,948
Population Served	25,300	37,679	25,037	33,214	38,429	53,626
Water Supply Source	Spring	Non-spring	Spring	Non-spring	Spring	Spring
Average Unaccounted-for Water (%):						
- existing	25.2	32.6	51.0	36.7	30.1	41.7
- after program	20.0	20.0	20.0	20.0	20.0	20.0
Project Cost (x Rp. 1,000) :						
- Base Cost	468,828.0	471,370.0	260,535.0	368,603.0	636,405.0	570,552.0
- Physical Contingencies	42,582.8	42,837.0	18,753.5	29,560.3	56,340.5	50,755.2
- Price Contingencies	25,464.0	25,916.0	11,449.0	17,939.0	34,093.0	31,312.0
- Value Added Tax	49,387.5	49,712.3	21,773.8	34,310.2	65,383.9	58,961.9
Grand Total Leak Control Program	586,262.3	589,835.3	312,511.3	450,412.5	792,222.4	711,581.1
- Rehabilitation Cost	352,260.0	609,190.0	284,235.0	501,300.0	437,100.0	5,554,100.0
Total Leak Control + Rehabilitation	938,522.3	1,199,025.3	596,746.3	951,712.5	1,229,322.4	6,265,681.1
Water Tariff and FIRR :						
- Existing Average Tariff (Rp/m3)	312	319	66	109	144	81
- FIRR (%)	10.66	27.05	16.33	0.74	1.24	-9.51
- Proposed Tariff (Rp/m3)	312	319	165	182	180	169
- FIRR (%)	10.66	27.05	37.12	18.39	5.47	56.33

Source : Lahmeyer Int. & Associates, August 1990.

Note : 1989 Exchange Rate - US \$ 1.00 = Rp. 1,720.00

IV. COST MODEL AND FEASIBILITY INDICATION OF WATER LOSS REDUCTION PROGRAM

4.1. GENERAL

The main purpose of this chapter is to utilize the results of the Water Loss Reduction Study in 20 towns for developing a representative cost model and feasibility indication of a similar water loss reduction program for small and medium towns in Indonesia.

The approaches to the cost model and feasibility indication of water loss reduction program presented in this chapter are quite simple and straightforward because of the lack of detail information, and the estimated project cost for 16 out of the 20 towns are somewhat preliminary. The overall procedures can be described as follows :

- analysis and selection of preliminary cost model of water loss reduction program, and
- analysis of economics of the water loss reduction program including possibility for the development of feasibility indication of water loss reduction program for small and medium size towns .

Prior to the analysis of unit cost parameters for the cost model, a review and evaluation of data on major components of unaccounted-for water and the recommended leak detection methods will be made as to facilitate the drawing of conclusions.

4.2. REVIEW OF DATA ON MAJOR COMPONENTS OF UNACCOUNTED-FOR WATER

Unaccounted-for water is a useful indicator of the overall integrity of a water system with respect to water loss. Male and Walski (1990) define the unaccounted-for water as the difference between water supplied to the system and water that is metered as it leaves the distribution system. Unlike water loss, which is defined as the portion of water supplied to the system that is not used legally or beneficially, the unaccounted-for water is consumed in legitimate, useful ways (e.g. fire fighting, street cleaning, sewer flushing) ; illegitimate ways (e.g. stolen water, broken or inaccurate meters) ; or wasteful ways (e.g. leakage, excessive breakage). Male, Noss and Moore (1985), Jeffcoat and Saravanapavan (1987), and AWWARF (1987) provide details on calculating unaccounted-for water. The value of unaccounted-for water is usually expressed as a percentage :

$$\frac{\text{water supplied - metered water use}}{\text{water supplied}} \times 100\ \%$$

The percentage of unaccounted-for water is a general description used to provide a quick assessment of how tight a distribution system is. Systems with unaccounted-for water values below 15 percent are considered to be in good condition, while those with values higher than 30 percent are considered poor (Male and Walski, 1990). In the latter case, efforts should be made to determine why the value is so high and where the water is being used or wasted.

Study of water balance in the four representative towns shows that the unaccounted-for water can be divided into two major components, i.e. physical losses (distribution system leakage) and non-physical losses. From the breakdown of components of unaccounted-for water shown in Table 3.11, the non-physical losses

were further divided into five components but no further breakdown was given for the physical losses.

For the purpose of evaluation, the components of unaccounted-for water obtained in the Water Loss Reduction Study are compared to the average unaccounted-for water components reported from 73 water utilities in New England, the United States of America as shown in Table 4.1.

Table 4.1. Comparison of Components of Unaccounted-for Water

<table>
<tr><th colspan="2">DESCRIPTION</th><th>Reported for New England, USA (%) 1)</th><th>Water Balance Study in 4 Towns (%) 2)</th></tr>
<tr><td>Non-Physical Losses :</td><td></td><td rowspan="3">14.3</td><td rowspan="2">12.5</td></tr>
<tr><td rowspan="2">a. Meter Slippage :</td><td>1. Over estimation of volume distribution</td></tr>
<tr><td>2. Consumer meter errors</td><td>3.8</td></tr>
<tr><td colspan="2">b. Illegal Connections</td><td>2.7</td><td>4.9</td></tr>
<tr><td colspan="2">c. Flushing</td><td>13.9</td><td>n/a</td></tr>
<tr><td colspan="2">d. Street Washing</td><td>1.5</td><td>n/a</td></tr>
<tr><td colspan="2">e. Fire Fighting</td><td>11.9</td><td>n/a</td></tr>
<tr><td colspan="2">f. Recreation</td><td>2.9</td><td>n/a</td></tr>
<tr><td rowspan="2">g. Other :</td><td>1. Administrative errors</td><td rowspan="2">7.0</td><td>8.4</td></tr>
<tr><td>2. Unmetered authorized usage</td><td>1.4</td></tr>
<tr><td colspan="2">Physical Losses (Dist. System Leakage) :</td><td rowspan="2">33.6</td><td rowspan="3">69.0</td></tr>
<tr><td colspan="2">a. Leakage</td></tr>
<tr><td colspan="2">b. Major Breaks</td><td>12.2</td></tr>
</table>

Source : 1) Male, Noss and Moore, 1985.
2) Lahmeyer Int. & Associates, February 1990[a].

From the above table it can be seen clearly that allowance for flushing, street washing, fire fighting and recreation are not given in the breakdown of components of unaccounted-for water for the four representative towns in the Water Loss Reduction Study. This reflects the general conditions in small and medium towns in Indonesia

where there are usually no records available for the water used for fire fighting, flushing and recreation. In the case of fire occurrences, local available water sources such as rivers or ponds are more oftenly used as the source of water for fire fighting. While street washing is done only in some major cities using raw water from the locally available water bodies. The distribution system leakage alone in the four towns made up 69 percent. This is considered high compared to the average about 40 percent reported in New England water utilities.

Based on the above comparison and consideration to local situation of the 20 towns covered by the Water Loss Reduction Study, the target of 20 percent unaccounted-for water designated after the project as described in Section 3.2.5 is considered reasonable with the note that allocation for street washing, flushing, fire fighting and recreation are not accounted for.

4.3. REVIEW OF THE RECOMMENDED LEAK DETECTION METHODS

Assessment of the appropriateness of the recommended methodology is difficult to make since the Water Loss Reduction Study gives no information of the amount of water lost through each type of leaks. Table 3.9 indicates only the number and location of leaks detected in the pilot zones of the four representative towns. The table shows that in the first two towns (Banda Aceh and Jambi) 80 to 90 percent of the number of leaks were found by visual inspection, while in the other two towns only about 9 percent of leaks were detected through visual inspection. The difference in number of leaks detected in those towns was explained by the fact that consumer meters in the latter two towns were repaired prior to the commencement of the leak detection program. However, the number of leaks does not always correspond with the volume of water lost. By comparing Tables 3.9 and 3.14, it can be seen that a

higher reduction in percentage of unaccounted-for water was achieved in Tasikmalaya and Purworejo, which both have smaller number of leak occurrences compared to the other two towns. This evidence shows that both visual inspection and sonic survey are required to achieve the expected level of unaccounted-for water.

Male and Walski (1990) described that determination of the quantity of water being lost from a distribution system is extremely important both from the point of view of assessing its general condition and in being able to identify and repair components contributing to water loss. According to Male, Noss and Moore (1985), two common approaches to determining water system leakage are :

1. water audit ; either a comprehensive water audit or a district audit.
2. leak detection survey using either one of the following equipments :
   a. sonic leak detection equipment which include geophone and aquaphone
   b. leak noise correlator
   c. mini probe sensors
   d. tracer gas

The sonic leak detection is the most common in the United States because it is generally cheaper and easier to perform (Male, Noss and Moore, 1985). For sonic approaches to be useful however, the operator must be well trained, know the limitations of the detection equipment, and be familiar with the distribution system.

Based on considerations to local distribution system conditions and for a long term development, the concept for water loss reduction program in the 20 towns as described in Section 3.2.6 could be considered adequately designed, especially if the control of unaccounted-for water is to be assigned routinely to each water utility. The general preparations and zone establishment as described in sections 3.2.6.1 and 3.2.6.2, which basically comprise institutional development, installation of master flow meters, mapping and recording of the locations and conditions of valves, pipes,

service connections and consumer water meters, could be considered as prerequisite activities prior to the execution of a leak detection and repair program.

Maintenance of accurate maps and records in general are considered as straightforward features but important (Male and Walski, 1990). Overlay maps with necessary information about technical data and condition of the system will certainly be helpful for easy analysis as they can highlight trouble spots. Male, Noss and Moore (1985) stated that knowledge of the distribution system itself is sometimes as important as an accounting of water uses. This is also essential if a program of preventive maintenance or repair is to be considered.

Consumer and water meter survey and inspection are required in order to obtain a more accurate figure of water consumption and efficiency of the distribution system. These activities will also lead to increasing revenue as underbilled and often illegal water use can be detected.

The recommended leak detection methodology as described in Section 3.2.6.3 is basically a combination of the water audit and sonic method. This combined method has proven to be effective in reducing water losses in the pilot zones of the four representative towns despite the fact that the implementation of the program is not financially viable for 6 out of the 20 towns covered by the Water Loss Reduction Study. The water audit method, however, is not fully recommended for small water utilities with less than 4,000 consumer connection.

Based on analysis of two different survey methods conducted in Westchester Joint Water Works (using sonic method) and Louisville Water Company (using a combined water audit and sonic method), Male, Noss and Moore (1985) concluded that the combined water audit and sonic method is more expensive per unit volume of avoided leakage, but secondary benefits such as information gained about the distribution system and the benefits gained from meter testing are greater compared to

sonic method alone. Furthermore, the sonic method leaves certain types of leaks undetected : some of large leaks such as broken mains or open blow-offs may emit sounds that are undetectable sonically (Siedler, 1982). The audit accounts for all the water in a district, ensuring that large leaks and breaks are not overlooked.

Considering the fact that there has been no leakage control done before, and the locations of leaks detected in the pilot zones of the four towns as shown in Table 3.9, where the leaks are randomly distributed throughout the system components, the combined water audit and sonic method would be the best choice.

4.4. COST MODEL OF WATER LOSS REDUCTION PROGRAM

This section aims at developing a simple cost model of a water loss reduction project that can be used for identifying a preliminary cost estimate if a similar program to those in the 20 towns is to be implemented in other small and medium towns in Indonesia. This preliminary cost estimate will then be used as the basis for a preliminary benefit and cost analysis of the program, which is expected could give an indication of the feasibility of the program.

Unlike the usual cost model which requires a deep assessment and complicated procedures, the model of preliminary cost indication of the water loss reduction program will be developed in the form of constant unit cost. For this purpose, five possible parameters of unit cost were considered :

- cost per percent reduction of unaccounted-for water;
- cost per volume (m^3) of avoided leakage per year;
- cost per unit flow (L/s) of water produced;
- cost per metre length of pipework; and
- cost per connection.

To perform the analysis, the necessary data from the 20 towns are retabulated as shown in Table 4.2. The figures of percent reduction of unaccounted-for water in column 7 are the difference between the existing unaccounted-for water mentioned in Table 3.12 and the target of percent unaccounted-for water after the project as described in Section 3.2.5. These figures are then multiplied by the average annual net production (m^3/year), mentioned in Table 3.12 column 6, and enter as the volume of avoided leakage in column 8. The costs of leak control program in column 9 are taken from Table 3.19. These costs cover all expenses for the implementation of the program in those towns, including the costs for labor (wages plus fringe benefits), except rehabilitation cost. Consideration for not taking the rehabilitation cost into account is based on the assumption that rehabilitation program is somewhat required for a better distribution system, with or without the water loss reduction program.

The unit costs per each parameter for those 20 towns are tabulated in Table 4.3 and a statistical evaluation for obtaining the unit cost parameter with the least variation between all of the towns is made and the results are summarized in Table 4.4.

The adequacy of data in Table 4.3 are assessed using an outlier method for 95 percent confidence level. An outlier may be regarded as significant if the ratio of

$$\frac{|\text{ extreme - overall mean }|}{\text{overall standard deviation}}$$

exceeds the values indicated in Table C.1 in Appendix C (from Davies & Goldsmith, 1984).

Any outlier found for each type of evaluation is discarded before calculating the mean ($\overline{x}$), the standard deviation (s) and the estimated standard error (SE).

The standard error of the mean is calculated as follows (Box, Hunter and Hunter, 1978) :

$$SE = \frac{s}{\sqrt{n}}$$

Where : s = standard deviation

n = number of observations

And the percent standard error relative to the average value (%SE) is calculated as follows :

$$\% SE = (SE/\bar{x}) X 100$$

Based on the evaluation of the percentage of standard error relative to the average value for every possible unit cost as shown in Table 4.3, it can be concluded that for overall 20 towns the cost per connection is considered as the most representative unit cost parameter since it has the lowest percent standard error relative to average value, i.e. 5.4 percent.

Table 4.2. Comparative Table of the Results of Water Loss Reduction Study in 20 Towns

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
TOWN	Source of Raw Water	System capacity (L/s)	Ave. annual net prod. (L/s)	No. of service connections	Total Length of Pipe (m)	Target UFW Reduction (%)	Volume of Avoided Leak (m3/year)	Cost of Leak Control Program x Rp. 1,000
Banda Aceh	Non-spring	300	279	10,786	196,820	25.5	2,244,969	1,340,376.1
Jambi	Non-spring	300	258	14,733	149,000	16.0	1,301,152	1,299,102.1
Tasikmalaya	Spring	175	160	6,230	91,770	39.5	1,991,057	784,756.9
Purworejo	Spring	112	107	4,358	35,330	10.4	351,623	603,605.8
Langsa	Non-spring	46	40	3,899	97,632	8.3	105,597	427,660.4
Pangkalan Brandan	Non-spring	40	34	2,434	36,700	15.1	160,393	295,919.3
Binjai	Non-spring	46	23	1,613	24,930	13.3	98,017	272,382.0
Tebing Tinggi	Non-spring	60	41	2,311	70,329	19.3	248,105	325,185.5
Kisaran	Non-spring	40	36	2,982	n/a	6.4	72,394	340,564.1
Rantau Prapat	Non-spring	40	33	2,790	33,700	3.9	40,224	316,350.4
Padang Sidempuan	Spring	78	65	2,796	72,900	31.2	640,711	365,556.1
Pakanbaru	Non-spring	280	147	10,090	187,200	5.6	258,954	1,077,803.9
Pangkal Pinang	Non-spring	88	21	3,378	n/a	8.3	54,505	227,107.6
Baturaja	Non-spring	55	57	3,619	45,400	20.2	360,201	318,442.1
Serang	Spring	89	89	4,544	83,300	5.2	146,604	586,262.3
Bekasi	Non-spring	89	83	8,453	173,100	12.6	331,300	589,835.3
Garut	Spring	85	77	3,546	22,600	31.0	756,917	312,511.3
Cilacap	Non-spring	200	62	3,900	92,300	16.7	327,931	450,412.5
Purwokerto	Spring	134	140	8,337	238,900	10.1	447,305	792,222.4
Magelang	Spring	390	382	9,948	177,300	21.7	2,612,657	711,581.1

Source : Lahmeyer Int. & Associates, August 1990.

Note : Exchange rate (1989) - US $ 1.00 = Rp. 1,720.00

Table 4.3. Comparative Table of the Summary of Evaluation Results of Unit Cost Parameters

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
TOWN	Cost/percent of UFW Reduction (Rp.)	Cost/m3 of avoided leak/y (Rp.)	Cost/l/s wate produced (Rp.)	Cost/m length of pipework (Rp.)	Cost per Connection (Rp.)
Banda Aceh	52,563,770	597	4,804,215	6,810	124,270
Jambi	81,193,880	998	5,035,280	8,719	88,176
Tasikmalaya	19,867,260	394	4,904,730	8,551	125,964
Purworejo	58,039,020	1,717	5,641,175	17,085	138,505
Langsa	51,525,350	4,050	10,691,510	4,380	109,685
Pangkalan Brandan	19,597,305	1,845	8,703,510	8,063	121,577
Binjai	20,479,850	2,779	11,842,695	10,926	168,867
Tebing Tinggi	16,848,990	1,311	7,931,355	4,624	140,712
Kisaran	53,213,140	4,704	9,460,115	n/a	114,207
Rantau Prapat	81,115,490	7,865	9,586,375	9,387	113,387
Padang Sidempuan	11,716,540	571	5,623,940	5,014	130,743
Pakanbaru	192,464,980	4,162	7,332,000	5,757	106,819
Pangkal Pinang	27,362,360	4,167	10,814,650	n/a	67,231
Baturaja	15,764,460	884	5,586,705	7,014	87,992
Serang	112,742,750	3,999	6,587,215	7,038	129,019
Bekasi	46,812,325	1,780	7,106,450	3,407	69,778
Garut	10,081,010	413	4,058,590	13,828	88,131
Cilacap	26,970,810	1,373	7,264,715	4,880	115,490
Purwokerto	78,437,860	1,771	5,658,730	3,316	95,025
Magelang	32,791,755	272	1,862,775	4,013	71,530
Discarded data (town)	Pakanbaru	Rantau Prapat	none	Purworejo	none
Average (x)	43,006,522.4	1,988.8	7,024,836.5	7,378.5	110,355.4
Std. Deviation	29,082,476.0	1,507.4	2,556,129.2	3,688.5	26,420.3
Std. Error	6,671,977.6	345.8	571,567.9	869.4	5,907.8
% Std. Error	15.5	17.4	8.1	11.8	5.4

In order to facilitate the preliminary benefit-cost analysis which will be discussed in Section 4.5, the possibility for grouping of the towns should be considered to account for the variation of unit cost figures that may actually occur.

Based on considerations to the technical and social aspects related to the distribution system, the towns are divided into three categories according to the two predominant parameters; number of service connection and net production capacity, as shown in Table 4.4 :

Table 4.4 Grouping of Towns for Cost Model of Water Loss Reduction Program

Towns Category	Parameters		Towns
	Net Production (L/s)	Number of Connection	
I	≥ 140	≥ 8,000	Banda Aceh, Jambi, Pakanbaru, Purwokerto and Magelang
II	80 - 140	4,000 - 8,000	Tasikmalaya, Purworejo, Serang and Bekasi
III	≤ 80	≤ 4,000	Langsa, Pangkalan Brandan, Binjai, Tebing Tinggi, Kisaran, Rantau Prapat, Padang Sidempuan, Pangkal Pinang, Baturaja, Garut and Cilacap.

The above grouping parameters are considered fit for all the towns with the exception of Bekasi and Tasikmalaya, which only fit one of the parameters. The decision to put them in category II was made after considering the fact that the figures of net production and number of connection shown in Table 4.2 for both of them are the total sum of two or more separate systems serving the towns and their vicinity. This consideration was taken in connection with the number of people served per L/s water consumed which is related to the average number of connection per unit water produced discussed in Section 4.5.2.

The same procedure is applied to each group of towns and the results are summarized in Table 4.5. These results are quite satisfactory where the relative standard error for each group is less than 10 percent. The rounded unit costs per connection mentioned in column 4 can be considered as a preliminary cost model of water loss reduction program in small and medium towns in Indonesia.

Table 4.5. Preliminary Cost Model of Water Loss Reduction Program

(1)	(2)		(3)	(4)
Category of Towns	Parameters of Grouping		Cost / Connection	
	Net Production (L/s)	Number of Connection	evaluation (Rp.)	Model (Rp.)
I	≥ 140	≥ 8,000	$\bar{x}$ = 97,164 S = 19,814.2 SE = 8,861.2 %SE = 9.1 %	97,000
II	80 - 140	4,000 - 8,000	$\bar{x}$ = 131,162.7 S = 6,539.5 SE = 3,775.6 %SE = 2.9 %	130,000
III	≤ 80	≤ 4,000	$\bar{x}$ = 114,365.5 S = 27,594.2 SE = 8,320.0 %SE = 7.3 %	115,000

4.5. ECONOMICS OF WATER LOSS REDUCTION PROGRAM

4.5.1. General

Determining the benefits of leak detection and repair program is difficult unless records of detailed characteristics of leaks and costs associated with their detection and repair are available. Male, Noss and Moore (1985) described that the economic

benefits of leak detection and repair can be calculated on the basis of the volume of leakage detected and repaired. The value assigned to each unit volume of leakage has often consisted of the costs for water acquisition, power, and chemicals (Pilzer, 1981), but sometimes costs for pumping, treatment, transmission and distribution are included as well (Rago and Crum, 1979). Many other potential benefits of leak detection and repair program are considered very difficult to quantify. They include (Brainard,1979; and Kingston, 1979) :

1. the gain of valuable information about the distribution system which can be used, for example, in setting priorities for replacement or rehabilitation program ;
2. reduced risk of contamination ;
3. increased firefighting capability ;
4. less wear and tear on pumps, plants, and distribution systems, since less water is being processed ;
5. fewer main breaks, and as a result, less property damage and fewer claims (and also lower insurance) ;
6. enhanced public relations and utility employee relations ;
7. delayed capacity expansion ;
8. more efficient and better quality leak repair, less overtime, and better repair crew safety ;
9. the inspection and exercising of valves and hydrants ; and
10. improved environmental quality.

The analysis of the benefit of water loss reduction program in this study follows in general the definition given by Male, Noss and Moore (1985) above. The benefit of the program will be the value of the amount of water that would have been lost from the leak had it continued to leak for a certain period from the time of discovery. The choice of the period is somewhat arbitrary. Based on considerations to

local condition and water supply management practice in small and medium towns in Indonesia, where evaluation is usually made every five years, and for the reason of simplification , a six year period is chosen for this preliminary analysis of the benefit of water loss reduction program. Thus the assumption is that leaks are detected six years earlier, as a result of the water loss reduction program, than they would if there were no program.

Since the water loss reduction program in the 20 towns (as the base data) has not yet been implemented, it is conservatively assumed that the leaks would have been leaking at the same rate at the beginning of the last year implementation of the program (the fourth year) as they were leaking at the beginning of the program, though actually there would be a significant reduction of leakage rate after three years implementation. Therefore, the benefit of implementing the water loss reduction program is based on the volume of leakage that is avoided by its earlier repair, the discovered leakage rate times six years.

Each unit volume of the avoided leakage will be assigned a value in order to quantify the benefit. The value system used in the Water Loss Reduction Study as described in Section 3.4.1.c will be adopted for this evaluation. The two cases are :

1. based on the average water tariff ; this is the case for those towns with water shortage problems, i.e. production capacity is less than demand for water, or population served is less than 60 percent; and
2. for the case that the net production capacity exceeds the existing water demand, the average production cost forms the basis for valuation of benefit in terms of saving in production cost.

However, due to unavailability of data for the second case, and since the most common situation in water supply systems in Indonesia is case number 1, the benefit analysis presented in this study will only consider the case number 1 where the avoided

leakage is valued with the average water tariff. Table 4.2 shows that four towns, Binjai, Pakanbaru, Pangkal Pinang and Cilacap, are likely to face the situation covered by case number 2. However, from data on consumer candidate waiting, the percentage of population served and number of new connections per year shown in Table B.4 (Appendix B), all towns, except Pangkal Pinang fit the requirements of case number 1. The conditions in the other three towns can be explained as follows (Lahmeyer Int. & Associates, August 1990) :

- for Binjai ; the nominal production capacity could not be reached due to water source shortage. Replacement of two out of four well pumps and installation of new wells are required to produce nominal capacity.
- for Pakanbaru ; the nominal capacity could not be achieved due to defects in raw water and distribution pumps and treatment plant.
- the new treatment plant in Cilacap not fully utilized yet as the distribution network for it is still to be constructed.

Therefore, data about water loss reduction study in Pangkal Pinang will not be taken into consideration for the rest of the evaluation.

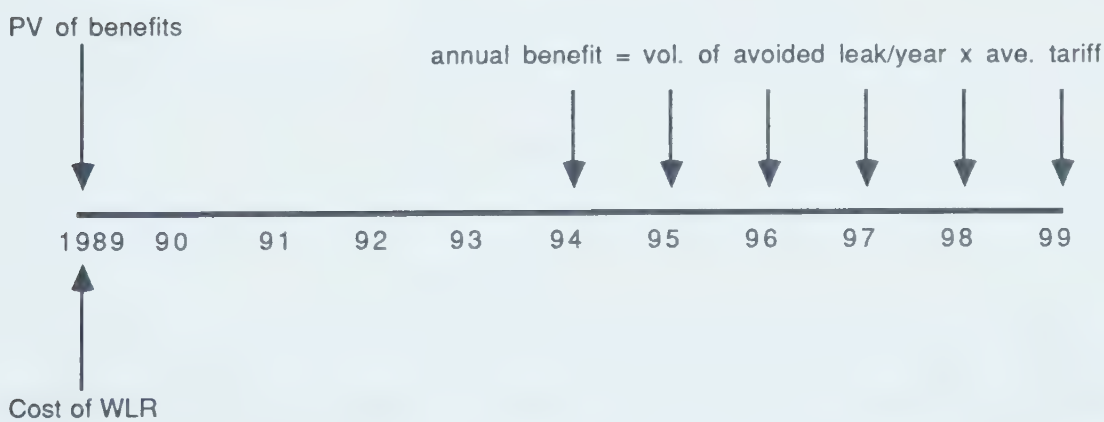
4.5.2. Correlation between Ratio of Benefits to Costs and Financial Internal Rate of Return

For the purpose of developing a feasibility indication, a correlation between ratio of benefits to costs (B/C) and financial internal rate of return (FIRR) is required in the case that the feasibility of a program is determined on the basis of its financial internal rate of return, as it applies to water supply development programs in Indonesia.

In this evaluation, the correlation between benefits to costs ratio and financial

internal rate of return will be estimated using the data from the Water Loss Reduction Study in 20 towns and by applying the same principle of benefit analysis as described in Section 4.5.1. Since the costs for project implementation for those towns are presented in 1989 local currency (Rupiah or Rp.), the benefits of the water loss reduction program will also be presented in 1989 Rupiah currency using the following assumptions :

- the proposed average tariff as shown in Table 3.20 is in effect after three years implementation of the program (1994) and remain constant five years later (1999).
- the interest rate used in the financial analysis of the Water Loss Reduction Study (9 percent) will be used as a constant discount rate to obtain the 1989 present value of benefits. Thus, the 1989 present value of benefits of the Water Loss Reduction Program is based on six years annuity of benefits from selling the volume of avoided leakage (m^3/year) at the constant average water tariff.



- from tables of discount and annuity factors (Sugden and Williams, 1978), for six year period of annuity and four years of discount value at 9 percent discount rate, a multiplier factor of 3.18 has to applied to obtain the 1989 value of benefits.

The necessary data as the basis for the calculation of benefits, such as cost of the leak control program , volume of avoided leakage per year, average water tariff and the corresponding financial internal rate of return, are taken from previous tables and restated in Table 4.6 together with the calculation of benefits and ratio of benefits to costs.

The correlation between the ratio of benefits to costs and financial internal rate of return was obtained using the available cricket graph software and the results for towns category I, II, and III are shown in Figures 4.1, 4.2 and 4.3, respectively. For all of the three categories of towns, the plots of data are best fitted with polynomial curves with coefficient correlation (R) $\geq$ 0.94. In this case, the financial internal rate of return data for Tebing Tinggi could be considered significant as an outlier as indicated in Figure 4.3.

The correlation between the ratio of benefits to costs and financial internal rate of return for every category of towns can be summarized as follows :

Towns category I : $FIRR = - 3.845 + 50.81\ (B/C) - 11.09\ (B/C)^2$ with regression coefficient (R^2) = 0.892

Towns category II : $FIRR = - 8.11 + 69.24\ (B/C) - 18.34\ (B/C)^2$ with (R^2) = 0.981

Towns category III : $FIRR = - 16.31 + 86.61\ (B/C) - 34.50\ (B/C)^2$ with (R^2) = 0.978

It is important to note here that these models valid only for the financial assumptions used in the Water Loss Reduction Study and are limited for use in the range of the available data as follows :

- for towns category I : range of B/C = 0 to 2.0
- for towns category II : range of B/C = 0 to 1.9
- for towns category III : range of B/C = 0 to 1.25

In this case study, due to the very limited available data, further subdivision of each category based on the type of their water sources is not considered. Actually, there would be a considerable difference in water tariff between a spring source water supply system and a system using non-spring sources (surface water or deep well), except in the situation where the location of spring is quite far from the town. The former is usually cheaper due to lower production cost as a result of less treatment required. However, consideration to source of water will be taken in the attempt to find a more sufficient model of average water tariff and will be discussed in Section 4.5.2.

Table 4.6. Data of Correlation Between B/C Ratio and FIRR

1	2	3	4	5	6	7	8
TOWNS	Source of Raw Water	Cost of Leak Control Program (Rp. x 1,000)	Volume of Avoided Leak (m3/year)	Ave. Water Tariff (Rp.)	Benefit (Rp. x 1,000)	Benefit to Cost Ratio	FIRR (%)
Category I							
Banda Aceh	Non-spring	1,340,376.10	2,244,969	282	2,013,198.40	1.50	37.92
Jambi	Non-spring	1,299,102.10	1,301,152	328	1,357,153.58	1.04	46.05
Pakanbaru	Non-spring	1,077,803.90	258,954	240	197,633.69	0.18	8.09
Purwokerto	Spring	792,222.40	447,305	180	256,037.38	0.32	5.47
Magelang	Spring	711,581.10	2,612,657	169	1,404,094.12	1.97	56.33
Category II							
Tasikmalaya	Spring	784,756.90	1,991,057	260	1,646,205.93	2.10	56.40
Purworejo	Spring	603,605.80	351,623	194	216,923.26	0.36	10.21
Serang	Spring	586,262.30	146,604	312	145,454.62	0.25	10.66
Bekasi	Non-spring	589,835.30	331,300	319	336,077.35	0.57	27.05
Category III							
Langsa	Non-spring	427,660.40	105,597	257	86,300.20	0.20	2.59
Pangkalan Brandan	Non-spring	295,919.30	160,393	259	132,102.88	0.45	13.45
Binjai	Non-spring	272,382.00	98,017	237	73,871.49	0.27	2.92
Tebing Tinggi	Non-spring	325,185.50	248,105	293	231,169.35	0.71	43.33
Kisaran	Non-spring	340,564.10	72,394	242	55,711.53	0.16	-6.45
Rantau Prapat	Non-spring	316,350.40	40,224	215	27,501.15	0.09	-8.17
Baturaja	Non-spring	318,442.10	360,201	214	245,123.98	0.77	27.80
Cilacap	Non-spring	450,412.50	327,931	182	189,793.35	0.42	18.39
Padang Sidempuan	Spring	365,556.10	640,711	200	407,492.20	1.11	39.35
Garut	Spring	312,511.30	756,917	165	397,154.35	1.27	37.12

Source : Lahmeyer Int. & Associates, August 1990.

Note : Exchange rate (1989) ; US $ 1.00 = Rp. 1,720.00

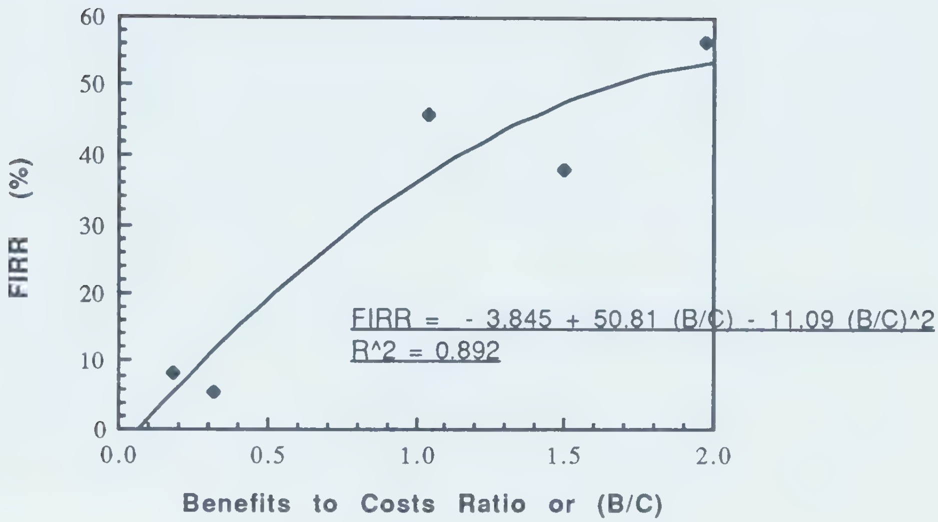


Figure 4.2. Variation of FIRR with B/C for Towns Category I

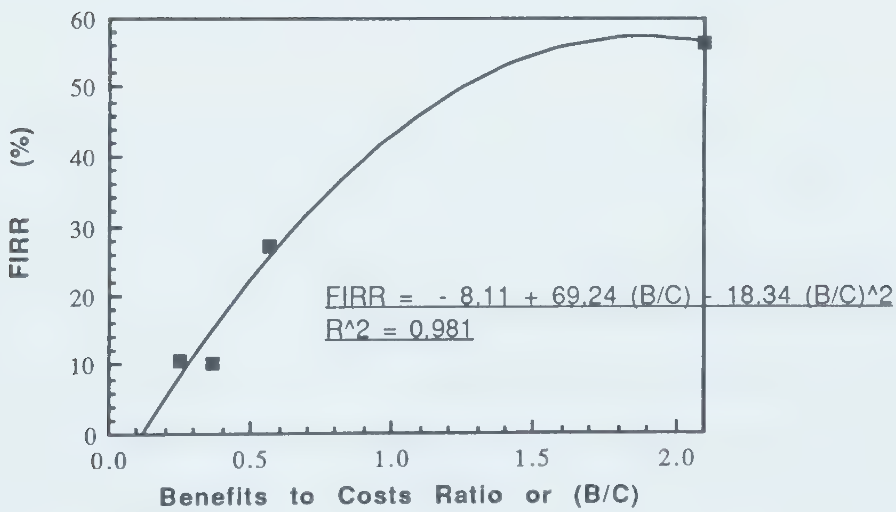


Figure 4.2. Variation of FIRR with B/C for Towns Category II

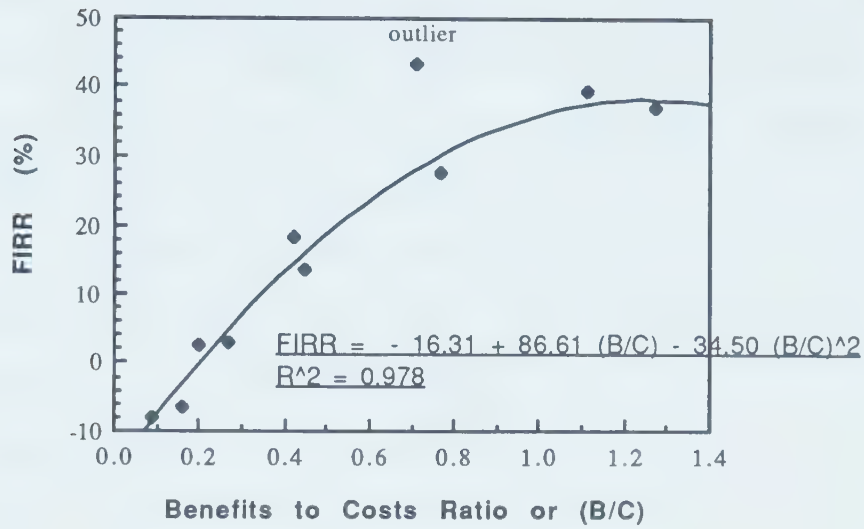


Figure 4.3. Variation of FIRR with B/C for Towns Category III

4.5.3. Feasibility Indication of Water Loss Reduction Program

With reference to the results of cost model and correlation between the ratio of benefits to costs and financial internal rate of return previously discussed, preliminary indications of water loss reduction program for small and medium towns in Indonesia can be developed if the average number of connection and water tariff for each group of towns are known. The cost of water loss reduction program has proven to be more depending on number of connection, while the benefit of the program relies mainly on the volume of avoided leakage and average water tariff.

For this reason, evaluation of data on the number of connections and the water tariff from the 20 towns is made and the results are shown in Table 4.7.

- the average number of connection is analyzed in terms of number of connection per unit flow of production, allowing two alternatives as shown in Table 4.7. A better result is obtained for the average number of connection per L/s water produced by combining towns categories I and II (alternative 2), compared to individual group analysis (alternative 1). The latter yields a quite contradictory situation when compared to reality, where the number of connections per L/s water produced in larger towns are usually less than those in smaller towns due to a higher per capita consumption. In both analysis, the data for Bekasi should be discarded as it is considered significant as an outlier. Combining those two categories of towns for obtaining an average value of number of connection per unit production might then be possible as all these towns could be classified as medium size towns (Coffey and Partners Pty. Ltd, 1989). The result is considered more sufficient as shown in Table 4.7 alternative 2; and will be adopted in the development of feasibility indication.

- a considerable difference between the average tariff for systems with spring source and those with non-spring sources can be clearly notified for towns under category I. This reflects the normal situation where the price of water is greatly influenced by its production costs. Since less treatment will be required, the water tariff from spring source water supply systems is usually less expensive than those with non-spring sources. Similar to the analysis for the average number of connections per unit production above, a combined analysis of the average water tariff for towns categories I and II, with further subdivision into their water sources, yields more sufficient results as shown in Table 4.7 alternative 2. These results will then be used as the model of average water tariff for those categories of towns.

- for towns under category III, the overall average number of connections per unit production and water tariff will be chosen as the model. Further division based on their sources of raw water is not considered due to very limited data available for towns

with spring sources.

After these additional analyses, all of the assumptions used for the development of a preliminary indication of the feasibility of water loss reduction program in small and medium towns in Indonesia can be summarized as shown in Table 4.8.

Table 4.7. Models of Average Number of Connection per L/s Water Produced and Water Tariff. (Alternative 1)

1	2	3	4	5	6	7	8
TOWNS	Source of Raw Water	Net Production (L/s)	No. of Connection	No. of Conn/l/s Net Production		Average Water Tariff (Rp.)	
				Data from 20 Towns	Model	Data from 20 Towns	Model
Category I							
Banda Aceh	Non-spring	279	10,786	39	Average = 50	282	Average = 240
Jambi	Non-spring	258	14,733	57	Std. Dev = 17.4	328	Std. Dev = 67.4
Pakanbaru	Non-spring	147	10,090	69	Std. Err = 7.8	240	Std. Err = 30.1
Purwokerto	Spring	140	8,337	60	% St.Er = 15.5	180	% St.Er = 12.6
Magelang	Spring	382	9,948	26		169	
Category II							
Tasikmalaya	Spring	160	6,230	39	Average = 44	260	Average = 270
Purworejo	Spring	107	4,358	41	Std. Dev = 6.4	194	Std. Dev = 57.8
Serang	Spring	89	4,544	51	Std. Err = 3.7	312	Std. Err = 28.9
Bekasi	Non-spring	83	8,453	102	% St.Er = 8.5	319	% St.Er = 10.7
Category III							
Langsa	Non-spring	40	3,899	97		257	
Pangkalan Brandan	Non-spring	34	2,434	72		259	
Binjai	Non-spring	23	1,613	70	Average = 68	237	Average = 225
Tebing Tinggi	Non-spring	41	2,311	57	Std. Dev = 17.3	293	Std. Dev = 38.8
Kisaran	Non-spring	36	2,982	83	Std. Err = 5.5	242	Std. Err = 12.2
Rantau Prapat	Non-spring	33	2,790	85	% St.Er = 8.0	215	% St.Er = 5.4
Baturaja	Non-spring	65	2,796	43		214	
Cilacap	Non-spring	57	3,619	64		182	
Padang Sidempuan	Spring	77	3,546	46		200	
Garut	Spring	62	3,900	63		165	

Note : Exchange rate (1989) ; US $ 1.00 = Rp. 1,720.00

Table 4.7. Models of Average Number of Connection per L/s Water Produced and Water Tariff. (Alternative 2)

1	2	3	4	5	6	7	8
TOWNS	Source of Raw Water	Net Production (L/s)	No. of Connection	No. of Conn/l/s Net Production		Average Water Tariff (Rp.)	
				Data from 20 Towns	Model	Data from 20 Towns	Model
Category I & II							
Banda Aceh	Non-spring	279	10,786	39		282	Average = 292
Jambi	Non-spring	258	14,733	57		328	Std. Dev = 40.1
Pakanbaru	Non-spring	147	10,090	69		240	Std. Err = 20.1
Bekasi	Non-spring	83	8,453	102	Average = 48	319	% St.Er = 6.9
					Std. Dev = 14.0		
Purwokerto	Spring	140	8,337	60	Std. Err = 4.9	180	Average = 223
Magelang	Spring	382	9,948	26	% St.Er = 10.4	169	Std. Dev = 61.0
Tasikmalaya	Spring	160	6,230	39		260	Std. Err = 27.3
Purworejo	Spring	107	4,358	41		194	% St.Er = 12.2
Serang	Spring	89	4,544	51		312	
Category III							
Langsa	Non-spring	40	3,899	97		257	
Pangkalan Brandan	Non-spring	34	2,434	72		259	
Binjai	Non-spring	23	1,613	70	Average = 68	237	Average = 225
Tebing Tinggi	Non-spring	41	2,311	57	Std. Dev = 17.3	293	Std. Dev = 38.8
Kisaran	Non-spring	36	2,982	83	Std. Err = 5.5	242	Std. Err = 12.2
Rantau Prapat	Non-spring	33	2,790	85	% St.Er = 8.0	215	% St.Er = 5.4
Baturaja	Non-spring	65	2,796	43		214	
Cilacap	Non-spring	57	3,619	64		182	
Padang Sidempuan	Spring	77	3,546	46		200	
Garut	Spring	62	3,900	63		165	

Note : Exchange rate (1989) ; US $ 1.00 = Rp. 1,720.00

Table 4.8. Assumptions Used for Developing the Feasibility Indication of Water Loss Reduction Program

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Towns Category	Grouping Parameters	Type of Source	UFW Target (%)	Ave # of Conn./ L/s prod.	Cost of WLR/conn. (Rp.)	Water Tariff (Rp.)	Benefits period (year)	Correlation between B/C and FIRR
I	Net prod. ≥ 140 L/s # of conn. ≥ 8,000	Spring Non	20	48	97,000	223 292	6	FIRR = -3.845 + 50.81 (B/C) - 11.09 $(B/C)^2$
II	Net prod 80 - 140 L/s # of conn 4000 - 8000	Spring Non	20	48	130,000	223 292	6	FIRR = - 8.11 + 69.24 (B/C) - 18.34 $(B/C)^2$
III	Net prod. ≤ 80 L/s # of conn ≤ 4,000	Spring/ Non	20	68	115,000	225	6	FIRR = -16.31 + 86.61 (B/C) - 34.50 $(B/C)^2$

Note : Exchange rate (1989) ; US $ 1.00 = Rp. 1,720.00

By applying all those assumptions, a general feasibility indication of water loss reduction program for small and medium towns in Indonesia can be estimated using any example of L/s net production for each category of towns as shown in Table 4.9.

The figures of number of connection in column (5) are obtained by multiplying the net production (L/s) in column (2) with the relevant average number of connection per L/s water produced from Table 4.8 column (5). These figures are then multiplied by the relevant cost per connection in Table 4.8 column (6) to arrive at the cost figures in column (8). The volume of avoided leakage per year in column (6) and benefits in column (7) are calculated as follows :

Column (6) = Column (1) x {Column (4) - 20%} x 365 x 86,400/100

Column (7) = Column (6) x 3.18 x relevant average water tariff

where : 3.18 = a multiplier factor for the present value of a 6 year-period annuity started from the fifth year as discussed in Section 4.5.1.

The relevant water tariff is taken from Table 4.8 column (7).

Finally, the figures of estimated financial internal rate of return in column (10) are derived from column (9) using the relevant correlation between FIRR and B/C as mentioned in Table 4.8 column (9).

The data of existing percentage of unaccounted-for water and financial internal rate of return for each category of towns were plotted as shown in Figures 4.4, 4.5 and 4.6. These figures depict the model that can be used to roughly predict the financial internal rate of return of a given existing level of unaccounted-for water if a water loss reduction program is to be implemented.

The low values of benefits to costs ratio, compared to the values of financial internal rate of return, is actually due to the length of benefit period used in this analysis is shorter than the 20 years term employed in the financial analysis of the Water Loss Reduction Study.

Table 4.9. Calculation of Feasibility Indication of Water Loss Reduction Program (1989 Exchange rate; US $ 1.00 = Rp. 1,720.0)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
Town Category	Net Production (L/s)	Source of Raw Water	Existing UFW (%)	Number of Connection	Volume of Avoided Leak (m3/year)	Benefits (Rp. x 1,000)	Cost of WLR Program (Rp. x 1,000)	B/C Ratio	FIRR
I	200	Spring	22	9,600	126,144.0	89,453.8	931,200	0.10	0.93
			25		315,360.0	223,634.4		0.24	7.72
			30		630,720.0	447,268.8		0.48	18.00
			35		946,080.0	670,903.2		0.72	27.01
			40		1,261,440.0	894,537.6		0.96	34.73
	200	Non-Spring	22	9,600	126,144.0	117,132.3	931,200	0.13	2.37
			25		315,360.0	292,830.7		0.31	11.04
			30		630,720.0	585,661.4		0.63	23.72
			35		946,080.0	878,492.0		0.94	34.22
			40		1,261,440.0	1,171,322.7		1.26	42.52
II	110	Spring	22	5,280	69,379.2	49,199.6	686,400	0.07	-3.24
			25		173,448.0	122,998.9		0.18	3.71
			30		346,896.0	245,997.8		0.36	14.35
			35		520,344.0	368,996.7		0.54	23.81
			40		693,792.0	491,995.7		0.72	32.10
	110	Non-Spring	22	5,280	69,379.2	64,422.7	686,400	0.09	-1.77
			25		173,448.0	161,056.9		0.23	7.13
			30		346,896.0	322,113.7		0.47	20.34
			35		520,344.0	483,170.6		0.70	31.54
			40		693,792.0	644,227.5		0.94	40.72
III	40	Spring or Non-Spring	25	2,720	63,072.0	45,128.0	312,800	0.14	-4.53
			30		126,144.0	90,256.0		0.29	5.81
			35		189,216.0	135,384.0		0.43	14.71
			40		252,288.0	180,512.1		0.58	22.18
			45		315,360.0	225,640.1		0.72	28.21
			50		378,432.0	270,768.1		0.87	32.81

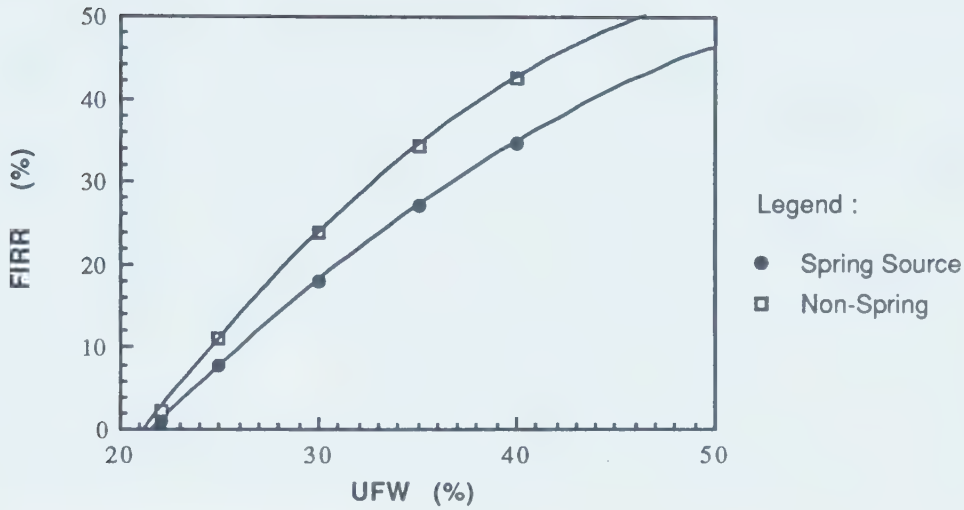


Figure 4.4. Variation of FIRR with UFW for Towns Category I

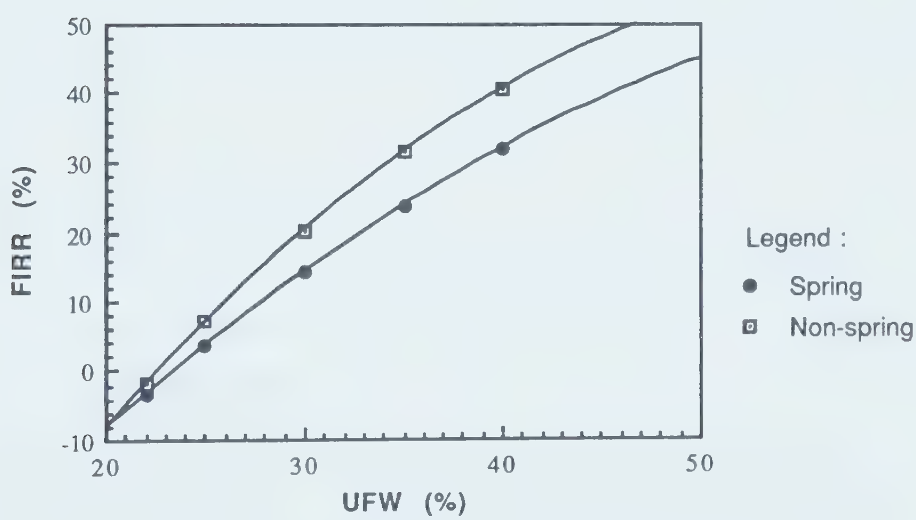


Figure 4.5. Variation of FIRR with UFW for Towns Category II

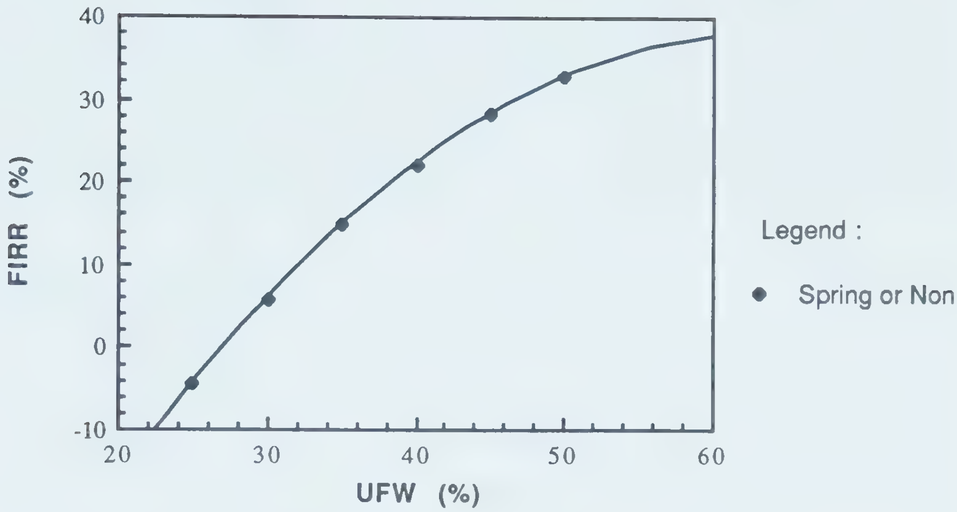


Figure 4.6. Variation of FIRR with UFW for Towns Category III

Using the same financial condition as for the Water Loss Reduction Projects in 20 towns, in which a minimum financial internal rate of return of 9 percent is used for the assessment of feasibility of projects, a criterion of minimum level of existing unaccounted-for water for conducting a similar water loss reduction program in each category of towns can be obtained from Figures 4.4 to 4.6 above and summarized as follows :

1. **Towns Category I.**

   - with spring source : Minimum existing UFW = 25.6 percent
   - with non-spring source : Minimum existing UFW = 24.5 percent

2. **Towns Category II.**

   - with spring source : Minimum existing UFW = 27.5 percent
   - with non-spring source : Minimum existing UFW = 26.0 percent

3. **Towns Category III.** : (spring or non-spring sources)

   : Minimum existing UFW = 32 percent

Evaluation of the adequacy of the model can be made by applying all the assumptions in Table 4.8 for obtaining internal rate of return figure for each of the towns covered by the Water Loss Reduction Study (excluding Pangkal Pinang). The results are then compared to the figures resulted from previous study as shown in Table 4.10.

By applying a minimum internal rate of return of 9 percent as a criterion for the feasibility of the program, the results are quite similar except for the four towns; Pakanbaru, Purwokerto, Serang and Binjai. However, better results are obtained when the water tariff data and the number of connections are used in conjunction with the other assumptions, as shown in Table 4.10 column (4) :

- from 5 towns in category I, only one town that is not in agreement with the results from previous study,
- from 4 towns in category II, only one town that is not in agreement with the results from previous study but with only slight difference to the expected one, and
- only 1 out of the 10 towns under category III which is not in agreement with the previous study.

Therefore, the cost model and feasibility indication could be considered sufficient for a preliminary assessment of similar water loss reduction program for small and medium towns when used on a regional or country-wide basis.

Table 4.10. Comparison of FIRR Values

(1)	(2)	(3)	(4)
TOWNS	FIRR (%)		
	from WLR Study	Based on Model entirely	Individual tariff & # of connection + Model
Category I			
Banda Aceh	37.92	49.12	52.85
Jambi	46.05	36.06	34.42
Pakanbaru	8.09	12.67	5.99
Purwokerto	5.47	18.19	11.09
Magelang	56.33	37.07	46.62
Category II			
Tasikmalaya	56.40	53.16	56.84
Purworejo	10.21	15.15	15.67
Serang	10.66	4.16	7.96
Bekasi	27.05	26.42	11.27
Category III			
Langsa	2.59	2.45	-1.04
Pangkalan Brandan	13.45	14.88	17.12
Binjai	2.92	11.85	12.34
Tebing Tinggi	43.33	21.22	33.06
Kisaran	- 6.45	-1.49	- 3.11
Rantau Prapat	- 8.17	- 7.00	- 9.08
Baturaja	27.80	22.45	22.95
Cilacap	18.39	17.41	14.06
Padang Sidempuan	39.35	33.70	38.04
Garut	37.12	33.56	35.21

V. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

Water loss reduction program by means of leak detection and repair was shown to be a cost-effective measure of reducing unaccounted-for water for most water supply systems. Previous studies show that various estimates of leakage for Indonesia's water utilities indicate that large amounts of water is lost by leakage. Therefore, the potential of leak detection and repair programs to reduce leaked water is probably large. The persistence of high levels of unaccounted-for water suggests that improved management of the assets and aggressive reduction programs may have substantial payoffs in producing net revenue gains or cost saving. Beyond the benefits associated with the program, the reduction of unaccounted-for water could play a substantial role in holding down new capacity requirements or in postponing the time when it would be necessary to undertake capacity expansions.

The previous study of water loss reduction program in 20 small and medium towns in Indonesia showed that a combined water audit and sonic method for medium towns and a single sonic method for small towns are proven to be appropriate and effective methods for reducing unaccounted-for water in those categories of towns. The study also showed that the program was not financially viable for some of the towns. It is evident that the economic efficiency of the program depends, to a large extent, on the characteristics of particular systems.

On the basis of discussion in the previous chapters, the feasibility of the water loss reduction program depends mainly on the number of connections, existing percentage of unaccounted-for water and the average water tariff for particular systems. Using three classifications of system production capacity, a generalized cost model and

feasibility indication of similar water loss reduction programs have been developed to assist in budget allocations and prioritizing the towns that should be included if the program is to be extended as a national program.

The models incorporate average conditions and unit costs and should not be used to provide definitive costing and feasibility for specific leak detection program or individual system. They are, however, considered sufficient when used for similar water loss reduction program in small and medium towns on a regional or country-wide basis and therefore a useful input into planning. The models can be used for predicting a preliminary cost estimate and feasibility indication of the same program in other small and medium towns, therefore the unnecessary time and budget for pre-investigation of the feasibility of the program in the towns, where the program will not be financially justifiable, can be avoided.

5.2. RECOMMENDATIONS

The general indication of minimum levels of unaccounted-for water for three categories of water supply systems presented in this report can be used for a quick assessment of possible feasibility of water loss reduction program in other similar systems. In order to obtain more accurate results, it is suggested to incorporate individual data on number of connection and average water tariff in combination with other assumptions and allowing the same analysis as employed in this report.

Since the Water Loss Reduction Projects in the 20 towns, whose feasibility study results are used as the base data for analysis, have not yet been implemented, it is therefore necessary to update the data once the projects are completed. Similarly, evaluation of the achievement of unaccounted-for water reduction target should be made for further analysis of the effectiveness of the recommended leak detection

methods.

A more detailed information about leak occurrences, the amount of water leaked, time spending and cost associated with leak repairs, on leak by leak basis, and the optimal surveying frequency would be very useful for further establishment of cost model and benefit analysis of the water loss reduction program.

REFERENCES

AWWARF, 1987, *Water Revenue and Losses ; Unaccounted-for Water*, American Water Works Association, Denver, Colorado.

Box, G.E.P., Hunter, W.G. and J.S. Hunter, 1978, *Statistics for Experimenters*, John Wiley & Sons, Inc., New York.

Brainard, F.S., Jr., 1979, *Leakage Problems and the Benefits of Leak Detection Programs*, Jour. AWWA, Vol. 71, No. 2, pp. 64-65.

Coffey and Partners Pty. Ltd., December 1989, *Water Supply and Sanitation Sector Study ; Draft Final Report Volume I & II*, prepared for the Directorate for Program Development, Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Davies, O.L. and P.L. Goldsmith, 1984, *Statistical Methods in Research and Production*, 4th edition, Longman Inc., New York.

Directorate for Program Development, Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia, July 1990, *Summary of Water Loss Reduction Project* , report presented to the Urban Development Coordination Board, the Government of Indonesia.

Garn, H., 1987, *Water Supply Investments in Developing Countries ; Some Technical, Economic, and Financial Implication of Experience*, Proc. ASCE International Conference on Resource Mobilization for Drinking Water Supply and Sanitation in Developing Nations, San Juan, Puerto Rico, Montanari, F.W. et al. (eds), ASCE, New York, pp. 227-233.

Garn, H. and A. Saravanapavan, 1987, *Reduction and Control of Unaccounted-for Water in Developing Countries*, Proc. ASCE International Conference on Resource Mobilization for Drinking Water Supply and Sanitation in

Developing Nations, San Juan, Puerto Rico, Montanari, F.W. et al. (eds), ASCE, New York, pp. 568-575.

Jeffcoat, P. and A. Saravanapavan, 1987, *The Reduction and Control of Unaccounted-for Water ; Working Guidelines*, World Bank Technical Paper, No. 72, Washington, D.C.

Keller, C.W., 1976, *Analysis of Unaccounted-for Water*, Journal AWWA, Volume 68, No. 3, pp. 159-162.

Kingston, W.L., 1979, *A Do-it-Yourself Leak Survey Benefit-Cost Study*, Journal AWWA, Volume 71, No. 2, pp. 70-72.

Lahmeyer Int. and Associates, February 1989, *Water Loss Reduction Project ; Inception Report*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Lahmeyer Int. and Associates, June 1989, *Water Loss Reduction Project ; First Interim Report Volume I & II*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Lahmeyer Int. and Associates, February 1990[a], *Water Loss Reduction Project ; Second Interim Report Volume I & II - Leak Detection Results*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Lahmeyer Int. and Associates, February 1990[b], *Water Loss Reduction Project ; Third Interim Report Volume I & II - Institutional Evaluation*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Lahmeyer Int. and Associates, April 1990, *Water Loss Reduction Project ; Feasibility Study for Banda Aceh, Jambi, Tasikmalaya and Purworejo*, prepared for the Directorate General of Human Settlements, Ministry of Public Works,

the Government of Indonesia.

Lahmeyer Int. and Associates, August 1990, *Water Loss Reduction Project ; Summary of Draft Prefeasibility Study for 16 Towns*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Lahmeyer Int. and Associates, January 1991, *Water Loss Reduction Project ; Final Report - Summary*, prepared for the Directorate General of Human Settlements, Ministry of Public Works, the Government of Indonesia.

Male, J.W., Noss, R.R. and J.C. Moore, 1985, *Identifying and Reducing Losses in Water Distribution Systems*, Noyes Publication, Park Ridge, New Jersey, U.S.A.

Male, J.W. and T.M. Walski, 1990, *Water Distribution System ; A Troubleshooting Manual*, Lewis Publishers Inc., Michigan, U.S.A.

Davies, O.L. and P.L. Goldsmith, 1984, *Statistical Methods in Research and Production*, 4^{th} edition, Longman Inc., New York.

Pilzer, J.E., 1981, *Leak Detection - Case Histories*, Jour. AWWA, Vol. 73, No. 11, pp. 565-567.

Rago, R.J. and D.E. Crum, 1979, *Distribution System Design Criteria and Leak Detection at East Bay Municipal District*, In-house report of the East Bay Municipal Utility District, Oakland, California.

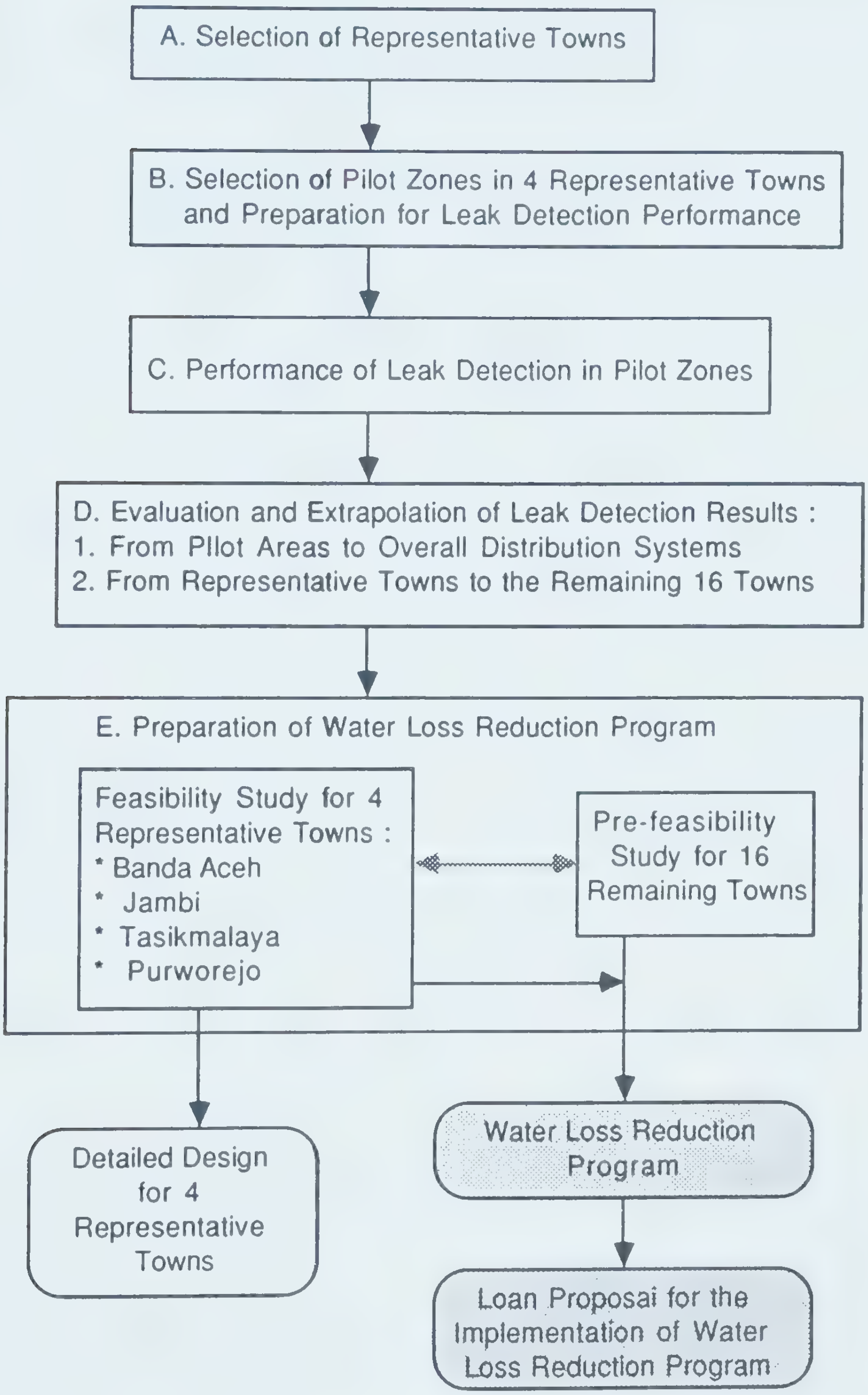
Siedler, M., 1982, *Obtaining an Analytical Grasp of Water Distribution Systems*, Jour. AWWA, Vol. 74, No. 12, pp. 628-630.

Sugden, R. and A. Williams, 1978, *The Principles of Practical Cost-Benefit Analysis*, Oxford University Press, Great Britain.

_________, *Policies for Urban Development in Indonesia*, 1987, the Secretariat of Urban Development Coordination Board, the Government of Indonesia.

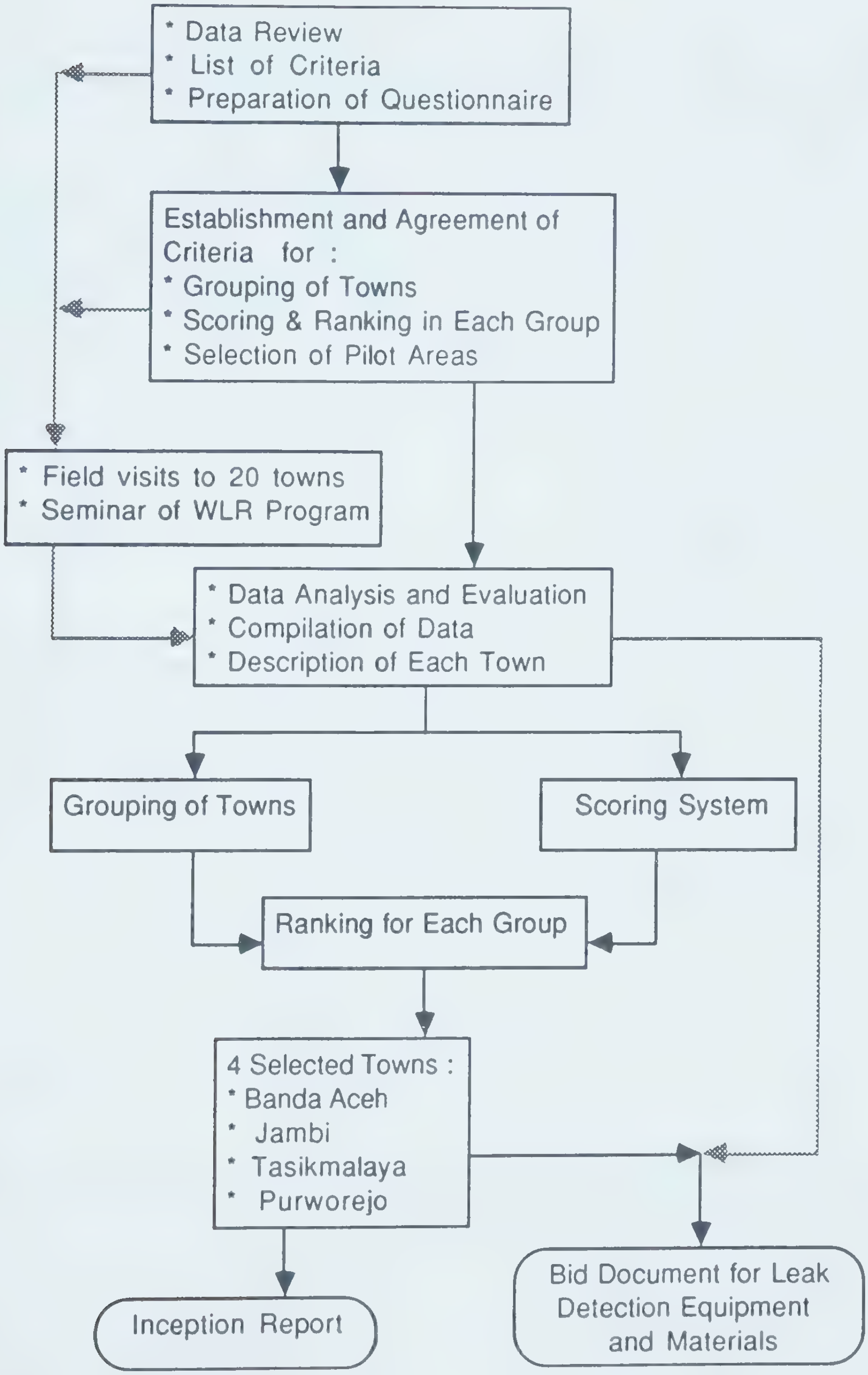
APPENDICES

APPENDIX A.1. Schematic Process of the Water Loss Reduction Study



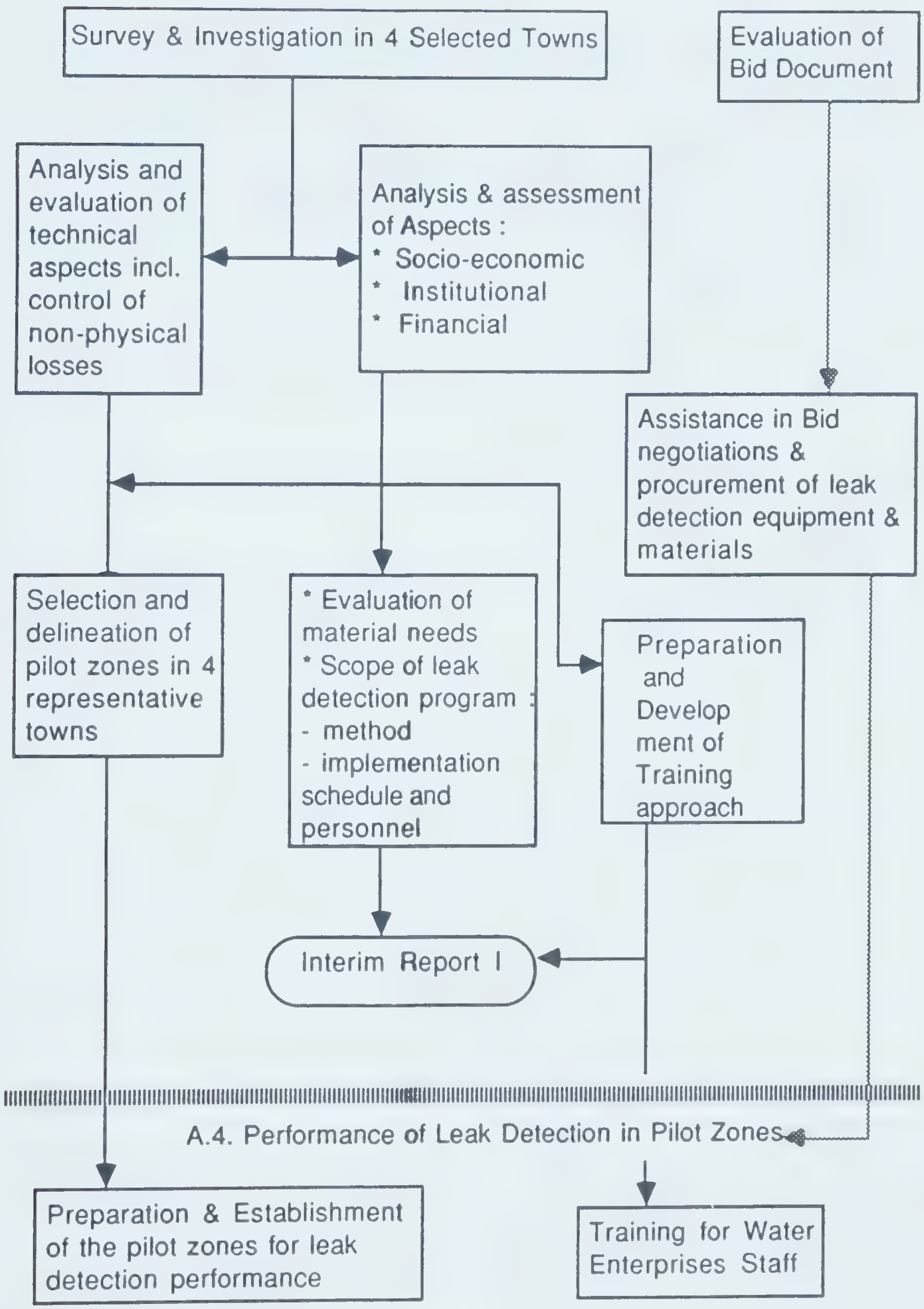
Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

APPENDIX A.2. Selection of Representative Towns



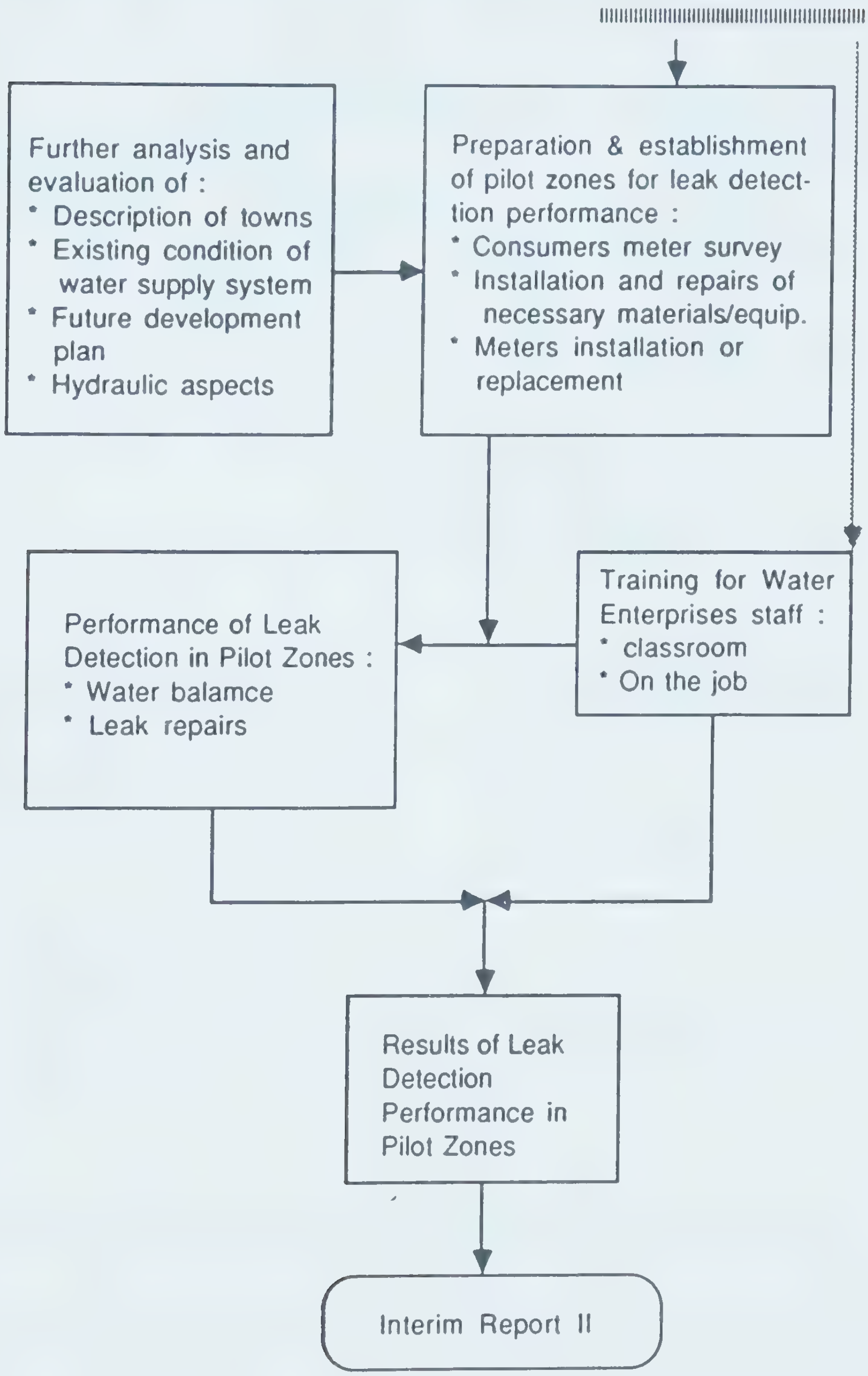
Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

APPENDIX A.3. Selection of Pilot Zones and Preparation for Leak Detection Performance



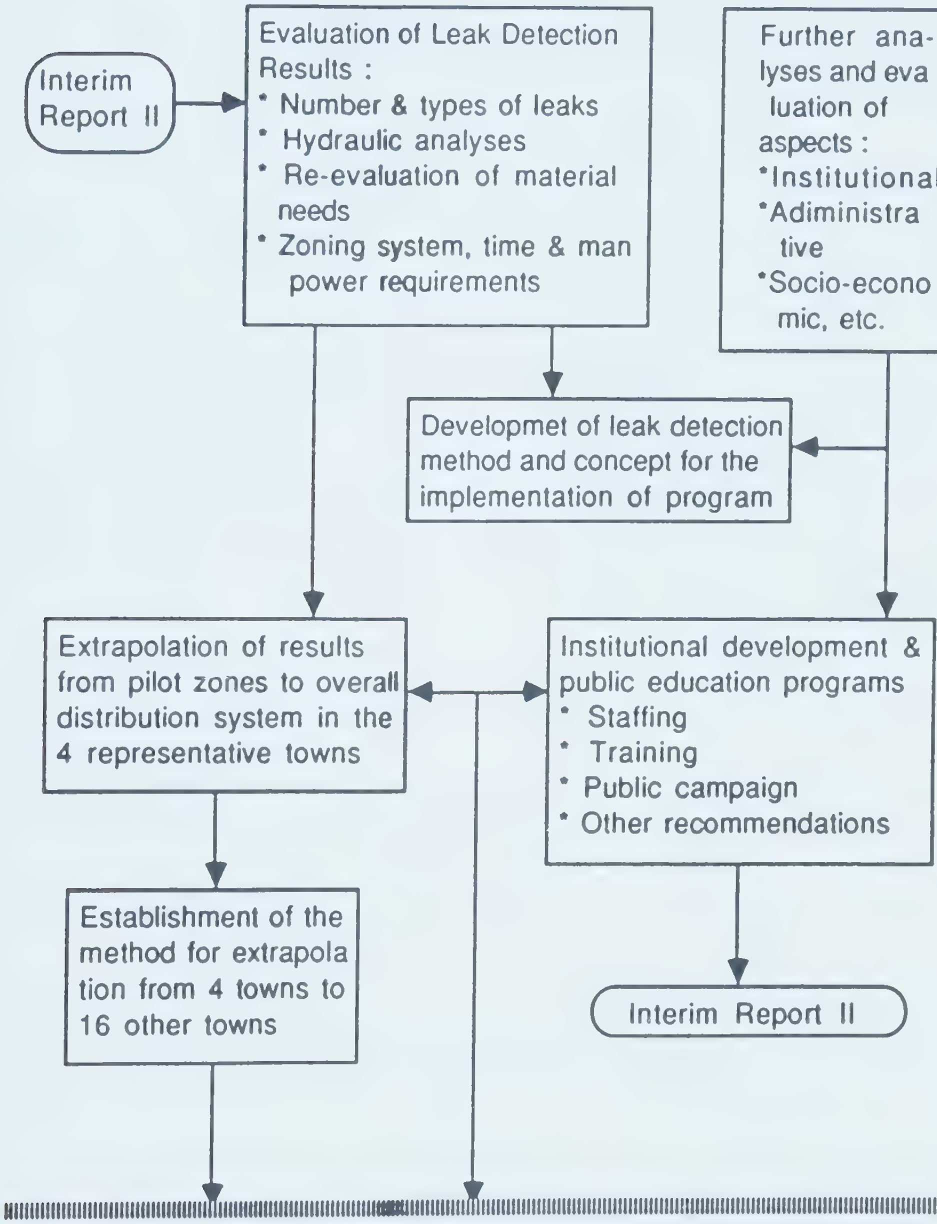
Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

APPENDIX A.4. Performance of Leak Detection in Pilot Zones



Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

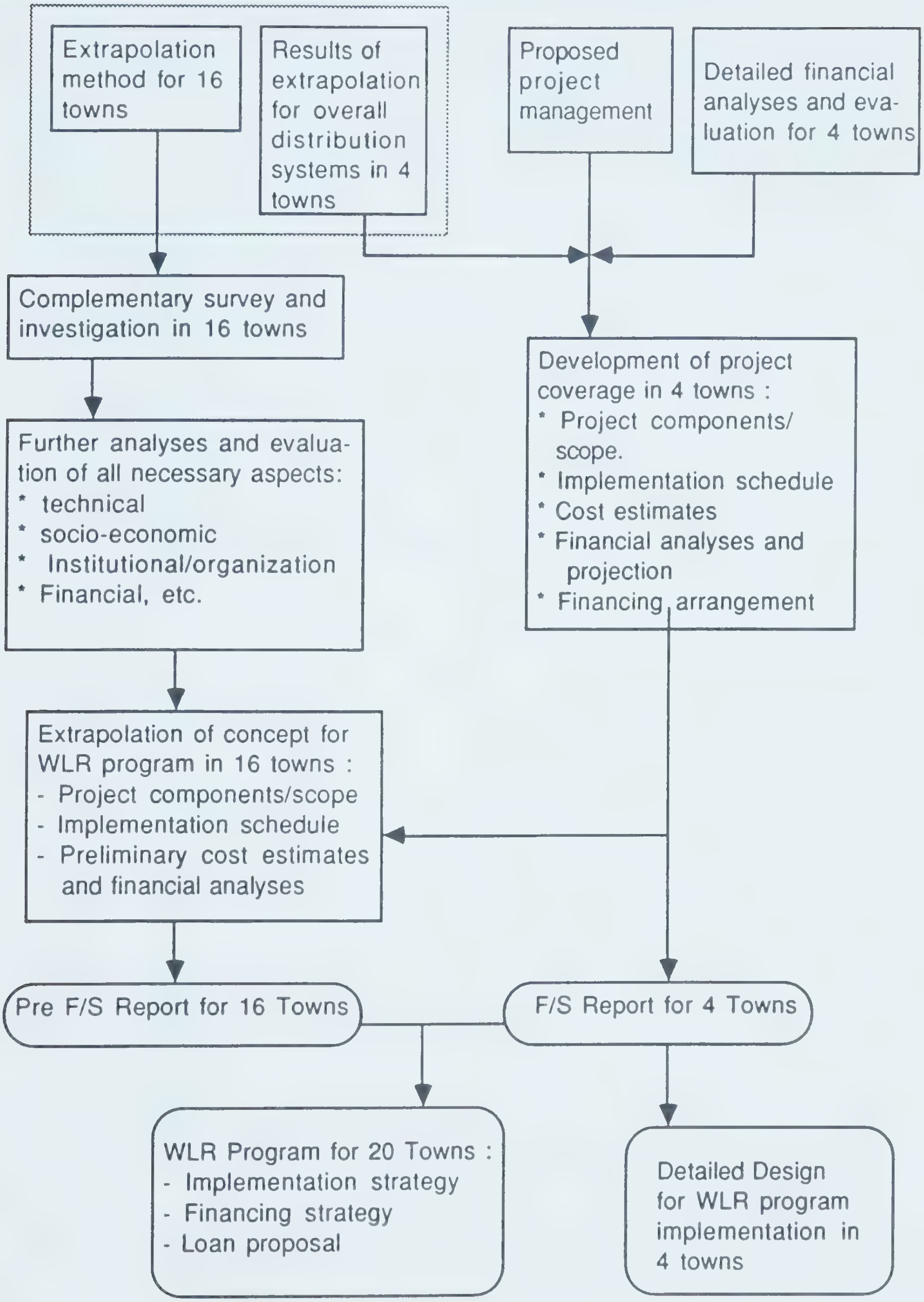
APPENDIX A.5. Evaluation and Extrapolation of Leak Detection Results



A.6. Preparation of Water Loss Reduction Program

Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

APPENDIX A.6. Preparation of Water Loss Reduction Program



Source : Directorate for Program Development, DGHS, MPW, GOI, 1990.

APPENDIX B

Table B.1. Criteria for Grouping, Ranking and Selection of Pilot Areas

NO	CRITERIA	Criteria Applicable For: Grouping	Criteria Applicable For: Ranking	Criteria Applicable For: Pilot Area	references number of Questionare
A.	GENERAL INFORMATION				
	01. Topography (Coastal Area, Lowland Plain Area/ Flat/ Upland Plain Area/Mountains)	x			
	02. Geographical Distribution (Sumatra Island, Java Island)	x			
	03. Level of Government (Capital of Province, Kabupaten, Kecamatan, Kotamadya, Kota Adminis-tratip)	x			
B.	SOCIO ECONOMIC ASPECTS				
	01. Size of Town/Population (Large, Medium, Small)	x	x		
	02. Population Density (High, Medium, Low)			x	
	03. Type of Area (Residential, Commercial, Industrial			x	
	04. Type of Housing (Permanent, Semi Permanent, Temporary)			x	
	05. Income (High, Medium, Low)			x	

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B

Table B.1. Criteria for Grouping, Ranking and Selection of Pilot Areas (Cont'd)

NO	CRITERIA	Criteria Applicable For: Grouping	Ranking	Pilot Area	references number of Questionare
C	GENERAL TECHNICAL ASPECTS				
	01. Water Supply System Capacity (< 50 l/s, 51-100 l/s, 101 - 200 l/s 201 - 300 l/s)	*	*		
	02. Type of Distribution System (Gravity, Pumping)		*	*	
	04. System Pressure (High, Medium, Low)		*	*	
	05. Pipe Materials (Steel, DIP, ACP, PVC)		*	*	
	06. Pipe Diameter (< 100 mm, < 250 mm, > 250 mm)		*	*	
	07. Age of Pipes (< 1970, 1970-1978, 1979-1983, > 198		*	*	
	08. Depth of Pipe Lines (< 0,50 m, 0,50-1,00 m, > 1,00 m)			*	
	09. Type of Water Meter (Single Jet/Multi Jet, Wet/dry)			*	
	10. Diameter of Water Meter (1/2", 3/4", => 1")			*	
	11. Soil Characteristics (Normal, Corrosive, Unstable)			*	
D.	LEVEL OF SERVICE				
	01. Percentage of Population Served (< 20%, 21-35%, 36-50%, > 50%)		*	*	
	02. Number of Consumer Connections (< 2000, 2001-5000, > 5000)			*	
	03. Average Water Consumption (< 100 l/p/s, 100-120 l/p/s, 120-150 l/p/s, > 150 l/p/s)		*	*	

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B

Table B.1. Criteria for Grouping, Ranking and Selection of Pilot Areas (Cont'd)

NO	CRITERIA	Criteria Applicable For			references number of Questionare
		Grouping	Ranking	Pilot Area	
	04. Hours of Service (< 16 h/d, 16-20 h/d, > 20 h/d)		x	x	
	05. Type of Consumer Connections (Domestic, Public Taps, Commercial, Industrial, Social)			x	
E.	WATER LOSS ASPECTS				
	01. Percentage of Total Water Losses (Unaccounted Water) (0-30%, 31-40%, 41-50%, > 50%)		x		
	02. Percentage of Physical Water Losses (0-10%, 11-20%, 21-30%, 31-40%)		x	x	
	03. Number of Illegal Connections (0-5%, 6-10%, > 10%)		x	x	
	04. Rate of Leakage (Leaks per Month) (0-15, 16-30, 31-50, > 50)		x	x	
F.	FUTURE EXPANSIONS				
	01. Population Growth Rate (High, Medium, Low)		x		
	02. Future Water Sources Capacity (Not Enough, Enough, More than Enough)		x		
	03. New Consumer Connections per Year (< 500, 500-1000, > 1000)		x		
	04. Consumer Candidates Waiting (High, Medium, Low)		x	x	

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B

Table B.1. Criteria for Grouping, Ranking and Selection of Pilot Areas (Cont'd)

NO	CRITERIA	Criteria Applicable For			references number of Questionare
		Grouping	Ranking	Pilot Area	
G.	INSTITUTIONAL AND FINANCIAL ASPECTS				
	01. Level of Management (PDAM, BPAM)	*	*		
	02. Type of Organization Structure (Type A, Type B, Type C)		*		
	03. Financial Situation (Rate of Return) (> 15%, 11-15%, 6-10%, < 6%)	*	*		
	04. Cost of Water Production (< 75, 75-100, 101-125, > 125)	*	*		
	05. Committment of PDAMs/BPAMs (Very High, High, Good, Fair)		*		

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B

Table B.2. Topographical/Geographical Comparison and Grouping of Towns

topography	Coastal Area		Lowland Area		Upland Area	
TOWN geography	Sumatera	Java	Sumatera	Java	Sumatera	Java
Banda Aceh	o					
Langsa	o					
Pangkalan Brandan	o					
Binjai			o			
Tebing Tinggi			o			
Kisaran			o			
Rantau Prapat					o	
Padang Sidempuan					o	
Pakanbaru			o			
Jambi			o			
Pangkal Pinang			o			
Baturaja					o	
Serang				o		
Bekasi				o		
Garut						o
Tasikmalaya						o
Cilacap				o		
Purwokerto						o
Purworejo				o		
Magelang						o
Sub total	3	0	6	4	3	4
Total	3		10		7	
Group Number	I		II	III	IV	
No.of towns/group	3		6	4	7	

APPENDIX B

Table B.3. Weight and Scores for Ranking Criteria

NO	CRITERIA	WEIGHT	SCORES
I.	WATER LOSS RATE		
	01. Percentage of Total Water Losses (Unaccounted Water)	10	
	* 1 - 30 %		1
	* 31 - 40 %		2
	* 41 - 50 %		3
	* > 50 %		4
II.	HIGHEST BENEFITS FROM WATER LOSS REDUCTION		
	02. Cost of Water Production	8	
	* < 75		1
	* 75 - 100		2
	* 101 - 125		3
	* > 125		4
	03. Consumer Candidates Waiting	8	
	* Low < 100		1
	* Medium 100-200		2
	* High > 200		3
	04. Leakage Repairs (Leaks per month)	8	
	* < 15		1
	* 15 - 30		2
	* 31 - 50		3
	* > 50		4
III.	FINANCIAL ABILITY & ASSISTANCE OF PDAM/BPAM		
	05. Financial Situation (Rate of Return)	7	
	* Poor < 6%		1
	* Fair 6 - 10%		2
	* Good 11 - 15%		3
	* Very Good > 15%		4
	06. Assistance of PDAMs/BPAMs	7	
	* Fair		1
	* Good		2
	* High		3
	* Very High		4

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B

Table B.3. Weight and Scores for Ranking Criteria (Cont'd)

NO	CRITERIA	WEIGHT	SCORES
IV.	WATER DISTRIBUTION SYSTEM CONDITIONS		
	07. Type of Distribution System (Gravity, Pumping)	6	
	* Gravity		1
	* Pumping		2
	08. Pipe Materials (ACP, CIP, DIP, GIP, PVC, STEEL)	6	
	* 3 Materials		1
	* 4 Materials		2
	* 5 Materials		3
	* 6 Materials		4
	09. Age of Pipes (Oldest pipes still in service)	6	
	* D > 1983		1
	* C 1979 - 83		2
	* B 1970 - 78		3
	* A < 1970		4
	10. Hours of Service	6	
	* > 20 h/d		1
	* 16-20 h/d		2
	* < 16 h/d		3
V.	WATER SUPPLY SERVICE CONDITIONS		
	11. Existing Water Sources Capacity	4	
	* More than Enough		1
	* Enough		2
	* Not Enough		3
	12. Percentage of Population Served	4	
	* > 50%		1
	* 36 - 50%		2
	* 20 - 35%		3
	* < 20%		4
VI.	OPPORTUNITIES FOR FUTURE EXPANSION		
	13. New Consumer Connections per Year	3	
	* < 500		1
	* 500 - 1000		2
	* > 1000		3
	14. Average Water Consumption	3	
	* > 150 l/p/d		1
	* 121 - 150 l/p/d		2
	* 100 - 120 l/p/d		3
	* < 100 l/p/d		4

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX B.4. Summary Comparative Table for Ranking Towns

NO	Town	Percentage Water Loss (%)	Cost of Water Production (Rp/m3)	Consumer Candidates Waiting (Number)	Leakage Repairs (Leaks per month)	Existing Water Sources Future Capacity	Percentage of Population Served (%)	Assistance of PDAM/BPAM	Type of Distri-bution System	Pipe Materials	Age of Pipes (years)	Hours of Service (h/d)	Rate of Return (%)	New Connections Per Year (number)	Average Water Consumption (l/p/d)
1.	Banda Aceh	42	84	287	5	N	38	High	Pumping	C, D, P	A, B, C	24	11.0	913	154
2.	Langsa	33	139	27	30	N	40	Fair	Gravity	A, G, P	B, D	24	7.0	318	87
3.	Pangkalan Brandan	38	109	18	10	E	33	High	Pumping	A, G, P	A, C	13	4.0	906	92
4.	Binjai	46	117	43	30	N	6	Fair	Pumping	A, G, P	A, B	18	8.0	68	85
5.	Tebing Tinggi	37	116	10	20	N	16	Fair	Pumping	A, D, G, P	A, C	24	4.2	120	96
6.	Kisaran	29	111	16	15	N	21	Good	Pumping	A, D, G, P	D	22	6.6	619	112
7.	Rantau Prapat	24	112	5	15	N	25	Fair	Pumping	A, D, P, S	A, C	24	3.0	504	110
8.	Padang Sidempuan	58	49	10	30	E	20	High	Gravity	C, D, P	A, C	12 - 24	3.0	444	98
9.	Pekanbaru	20	134	120	5	E	22	Good	Pumping	A, C, G, P	B, C	24	7.0	719	176
10.	Jambi	38	145	305	220	N	37	Very High	Pumping	C, D, G, P	B, C	24	3.9	1224	187
11.	Pangkal Pinang	30	106	0	9	N	13	Fair	Gravity/Pumping	A, C, G, P	A, B, D	3 - 24	3.0	-112	65
12.	Baturaja	37	123	57	20	E	35	Good	Gravity	D, G, P	C	24	5.0	205	118
13.	Serang	27	72	300	17	N	39	Good	Gravity	A, G, P	C	24	22.0	453	139
14.	Bekasi	32	130	,300	12	N	16	Good	Pumping	A, G, P, S	B, D	24	1.0	620	84
15.	Garut	38	33	0	20	N	27	Good	Gravity	G, P, S	A, B	24	5.0	85	147
16.	Tasikmalaya	46	11	100	82	N	31	High	Gravity	A, P, S	A, C	24	11.0	218	88
17.	Cilacap	48	119	54	50	N	11	Fair	Gravity	A, P, S	C	24	4.6	599	123
18.	Purwokerto	24	95	37	25	E	26	High	Gravity	A, C, D, G, P	A, C	24	8.0	502	93
19.	Purworejo	32	88	45	70	M	22	High	Gravity/Pumping	A, G, P	A, B	24	11.0	253	150
20.	Magelang	34	75	97	100	E	59	High	Gravity	A, G, P, S	A, B	24	13.0	298	156

Note :
* Pipe Materials : A = ACP, C = CI, D = DIP, G = GIP, P = PVC, S = STEEL
* Age of Pipe : A = < 1970, B = 1970-1978, C = 1979-1983, D = > 1983
* Existing Water Sources : N = Not Enough, E = Enough, M = More than Enough

Source : Lahmeyer Int. & Associates, June 1989.

APPENDIX C

Table C.1.Values of Outlier Ratio at Two Levels of Significance

No. in Sample	α 0.05	α 0.02	No. in Sample	α 0.05	α 0.02
3	1.15.	1.15	18	2.65	2.82
4	1.48	1.49	19	2.68	2.85
5	1.71	1.75	20	2.71	2.88
6	1.89	1.94	21	2.73	2.91
7	2.02	2.10	22	2.76	2.94
8	2.13	2.22	23	2.78	2.96
9	2.21	2.32	24	2.80	2.99
10	2.29	2.41	25	2.82	3.01
11	2.36	2.48	30	2.91	3.10
12	2.41	2.55	35	2.98	3.18
13	2.46	2.61	40	3.04	3.24
14	2.51	2.66	45	3.09	3.29
15	2.55	2.71	50	3.13	3.34
16	2.59	2.75	60	3.20	3.41
17	2.62	2.79	70	3.26	3.47
18	2.65	2.82	80	3.31	3.52
19	2.68	2.85	90	3.35	3.56
20	2.71	2.88	100	3.38	3.60

Source : Owen and Goldsmith , 1984.